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REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

1941 - 1942

HARRY S. LADD Chairman

Presented at the Annual Meeting of the
Division of Geology and Geography
National Research Council
May 2, 1942

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NATIONAL RESEARCH COUNCIL

DIVISION OF GEOLOGY AND GEOGRAPHY

WASHINGTON, D. C.

* REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

May 2, 1942

Appendix N of Annual Report
of the Division for 1941-1942

*(See also previous report of May 3, 1941
of the Subcommittee on the Ecology
of Marine Organisms)

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Remington Kellogg	H. C. Stetson
Kenneth E. Lohman	T. Wayland Vaughan

(First edition, December 1942)
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REPORT OF THE COMMITTEE ON

MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

INTRODUCTION

During the past year the Subcommittee on the Ecology of Marine Organisms has been made a full Committee and its title slightly changed to emphasize the fact that its interests are primarily paleontological. One new member, Gordon Gunter, a marine biologist, has been added to the group.

The aims of the Committee are similar to those of the Subcommittee and may be briefly stated, as follows:

1. (a) To obtain information on current and recently completed activities.
   (b) To present its findings in the form of a current bibliography and of summary reviews.
   (c) To distribute both as widely as possible among geologists and biologists.

2. (a) To stimulate and promote needed types of ecological investigations.
   (b) To prepare an annotated bibliography on paleoecology.
   (c) Possibly, at a later date, to prepare a special treatise on ecology that would stress geological interpretation.

The war has greatly curtailed most activities in marine ecology. Work of oceanographic expeditions has practically ceased, the ships formerly used for such work being now in harbor or detailed to naval operations. One of the latest expeditions was that of the steel Diesel schooner "Askoy" which operated in the eastern tropical Pacific between February 9 and May 26, 1941 with a party from the American Museum. A brief report covering this expedition was published by Robert Cushman Murphy in Science (vol. 94, pp. 57-58, 1941).

Certain types of biological work at marine stations have either been greatly curtailed or entirely eliminated because of the pressure of activities directly connected with the war. This is true at the Woods Hole Oceanographic Institution and the Scripps Institution of Oceanography. E. L. Packard, Director of Research at the Institute of Marine Biology at Coos Bay, Oregon, reports that practically all activities have been discontinued for the duration of the war. According to Director William Beebe, the Tropical Research Station of the New York Zoological Society at Nonsuch in Bermuda was closed early in 1941. In England a limited amount of work of certain types is being done at the Marine Biological Station at Port Erin, Isle of Man. (Science, vol. 95, No. 2471, 1942). The Plymouth Laboratory, heavily damaged by enemy action, has been repaired and some work is being carried on.

The activities of the present committee will be considerably curtailed during the emergency. At the present time one member is in the Navy, another

in the Army, and a third is occupied with new duties in Honolulu. Four of the remaining six members are devoting part or all of their time to activities directly connected with the war.

With the unexpected death of Dr. Charles Branch Wilson on August 18, 1941 marine biology lost one of its outstanding figures. In an obituary (Science, vol. 94, pp. 358-359, 1941) Waldo L. Schmitt made brief reference to three major works on copepods completed by Dr. Wilson in his later years. These are still in manuscript form but are to be published at an early date by the U. S. National Museum and the Carnegie Institution of Washington. Regarding these works Dr. Schmitt says:

"The first of these manuscripts, and perhaps the most important in Dr. Wilson's own opinion, deals with the copepods of the marine plankton taken on the last cruise of the ill-fated non-magnetic yacht, CARNEGIE. This report, which was submitted for publication several years ago, for the first time in the history of oceanography gives the directly comparable results of simultaneous three-level tows made in all oceans with identical gear, accompanied by full station data, including temperature, salinity, density, phosphates and hydrogen ion concentration. In his painstaking tabulation of the species of copepods in every haul and their abundance at each of the three levels investigated, involving the microscopic inspection of many thousands of individual copepods, Dr. Wilson has made available a biologic record of a group of organisms of highest importance in the economy of the seas such as has never been achieved by any marine expedition.

"The second of these manuscripts completes the study of the last remaining unidentified parasitic copepods in the national collections, describing 6 new genera and 15 new species. Through the almost unaided efforts of Dr. Wilson, the National Museum now possesses the most comprehensive collection of parasitic copepods in the world.

"The third and last of these manuscripts sets forth the results of his study of the copepods of the plankton and dredged material amassed during the greater part of the useful life of the former U. S. Fisheries Steamer ALBATROSS. In time this covers nearly a quarter of a century, from 1887, when the ALBATROSS made her memorable passage from the Atlantic to the Pacific by way of the Straits of Magellan, to 1910, which marked the close of the three-year ALBATROSS Philippine Expedition. This monumental report makes important additions to the records of distribution of 469 species of copepods, describes 32 new species, and describes the hitherto unknown opposite sex of twenty-eight."

PROPOSED BIBLIOGRAPHY OF PALEOECOLOGY

Several geologists interested in the work of the Committee have suggested that consideration be given to the preparation of an annotated bibliography of paleoecology. The literature in this field is widely scattered and much of it is little known as there are numerous instances

where paleoecological material forms but a minor part of a large report and finds no place in the title. To bring even the most important references together would be a considerable task. The proposal has been discussed with members of the Committee and with Mr. Bucher, Chairman of the Division. All appear to favor it strongly, Mr. Bucher pointing out that it is precisely the sort of undertaking for which the National Research Council was created. Obviously it will be necessary to enlist the aid of numerous specialists if the work is to be completed within a reasonable time. In some instances a given geologist may be assigned an entire organic group but in others it will appear more desirable to subdivide on the basis of chronology or geography, or both. A bare beginning has been made to date and only the following assignments have been made and accepted:

Hexactinellid Sponges -- Kenneth E. Caster
Scleractinia -- T. Wayland Vaughan and by John W. Wells
Brachiopods -- G. Arthur Cooper
Diatoms -- Kenneth E. Lohman
Problematical fossils -- Kenneth E. Caster
Mollusca of the Tertiary of northeast Mexico,
Eocene of Rio Grande Embayment,
Claiborne of east Gulf region. } -- Julia Gardner

Final assignments of all other groups are yet to be made. The Committee will welcome volunteers to prepare material in fields with which they are familiar.

CURRENT ACTIVITIES

EASTERN UNITED STATES

Dr. George L. Clarke of the Woods Hole Oceanographic Institution has submitted a brief report on preliminary work with a quantitative bottom dredge.

"During the summer of 1941 a survey of the bottom fauna of Menemsha Bight (Vineyard Sound, shore of Martha's Vineyard, Massachusetts) was undertaken, with the collaboration of Mr. Richard Lee, as a preliminary to quantitative bottom investigations on Georges Bank. The dredge employed was a commercial 'rehandling bucket' arranged so that it could be operated from one cable. Since the dredge, with its opening of 2 x 3 feet, was much larger than any employed by earlier workers and since it bit well into the bottom even when hard, the sample of bottom material obtained was of satisfactory size (10 to 50 liters) for quantitative treatment.

"All organisms (above the size which passed through the finest screen of 8 meshes per inch) were sieved out of the samples, identified, enumerated, and measured for both wet weight and dry weight. From the latter measurements the organic matter present was determined and served as an index of the potential food supply represented by the bottom fauna. When the catches from

the 90 stations made in Menemsha Bight were analyzed in this way, it was possible to plot in a preliminary manner the distribution of animal material both qualitatively and quantitatively for the area."

Prof. Ralph W. Dexter of Kent State University in Ohio has made a bioecological study of the marine communities inhabiting a tidal inlet at Cape Ann, Massachusetts during the summer seasons of a five year period. Twenty-four intertidal stations were established from one end of the inlet to the other. Eleven were placed on either side and two on bars in the middle of the waterway. These were selected to include representatives of all of the marine communities living in the inlet. In addition the entire channel way was dredged.

The results of the Cape Ann investigation were submitted as a thesis at the University of Illinois and an abstract published there in 1938. Since that date Dexter has done additional field work and his main study is being revised for publication within the next year. The results of the dredging will probably be published as a separate paper.

Mr. E. R. Eller of the Carnegie Museum in Pittsburgh, Pennsylvania, is studying the paleoecology of the scolecodonts, fossil polychaete worm jaws. He reported as follows:

"Not considering the writer's attempts, only four or five papers have been published on the subject since 1879. The work for the most part has been of a taxonomic nature with little thought of the relationship of the annelids to their surroundings or to the other fauna. Inferences may be made, however, by studying the morphology and habitats of the modern polychaete and applying the results to the fossil remains of annelids and the lithological characteristics of the strata in which they are found.

"Paleontologists have always considered scolecodonts rare. Since the writer has found them throughout the Paleozoic rocks, this would seem not to be the case. The jaw parts, maxillae and mandibles, of the fossil forms are very similar to those of Recent species. If jaw apparatus is indicative of their morphology in general, then scolecodonts have evolved little since Paleozoic times. This suggests that their habitats, sedentary character, and burrowing habits were probably the same. Evidence so far accumulated suggests that both Paleozoic and Recent polychaetes live in about the same environment.

"Modern polychaetes have a world-wide distribution. They are usually found in shallow water and in inter-tidal areas, although they occupy deeper zones of the sea as well. They seem to prefer a bottom composed of muddy material containing vegetable matter and the remains of other organic life. This type of material is more suitable for burrows and food. Scolecodonts are also found in greater numbers, both species and specimens, in this type of sediment. Fossil remains, however, are found in all phases of limestones, sandstones, and shales.

"To consider a particular case - the Manitoulin beds, a lower Silurian member of the Cataract of New York and Ontario, contain a scolecodont fauna throughout their areal extent. The southeastern end or the near-shore deposits are of detrital material containing ripple-marked layers. They become thickened and increasingly calcareous and dolomitic northwestward. The distribution of the scolecodonts, both species and individuals, is greatest at the southeastern end and many scores of specimens may be found in the impure sandstone strata. The ripple-marked layers, containing worm trails and burrows, are particularly rich in scolecodonts. Northwestward the numbers decrease until a locality known as the Forks of the Credit is reached. Here the beds become slightly impure and the number of scolecodont species and specimens increases noticeably. Farther north, on Manitoulin Island, a number of bioherms (cryptostomatous bryozoans) are developed and at the edges the number of specimens increases to a marked degree. Polychaetes are very common in the South Seas adjacent to coral reefs. Thus, by taking into consideration environment, number of species and specimens of a modern polychaete locality, it could be suggested that the Manitoulin sea was a warm, shallow, well-aerated body of water of not too high salinity.

"In the Erindale, Upper Ordovician, near Toronto, Ontario, an interesting assemblage of scolecodonts occurs in an almost pure sandstone matrix. The jaws are deposited at the crests of very low, reworked ripple-marks and as wave or swash marks. At some places the surface is darkened by their presence and more than five hundred jaws or jaw fragments were counted to the square inch. In general, the habits of modern polychaetes suggest that the almost pure sandstone matrix in which fossil jaws are contained was not their habitat. Perhaps many of the jaws were washed in a short distance, or, since many of them are water-worn, perhaps they were rolled about considerably. In the South Pacific Islands and elsewhere countless myriads of annelids have been observed on certain spawning days; perhaps just such an occurrence was the reason for so many jaws being deposited at this locality. Other theories might be suggested.

"Associated fauna does not seem to shed any particular light on the paleoecology of scolecodonts. They have been found in all types of assemblages and in horizons void of any other fossil remains. The fact that the jaws are not affected by acids may account for their appearance. Scolecodonts are so fragile that light pressure of a camel's-hair brush may shatter them. No definite conclusions will be made yet, but evidence suggests that the very small and delicate specimens measuring less than 1 mm. were inhabitants of deep seas, while the larger, heavier forms occupied relatively shallow areas. The ecological relationship of the earthworm to its habitat is well understood, but little is known of its near relative the polychaete. It is evident from the burrows, tubes, trails, and the disturbed condition of some strata that these marine worms had considerable influence on associated Paleozoic life and sediments."

Wilson M. Laird, State Geologist of North Dakota, has completed a thesis at the University of Cincinnati dealing with the stratigraphy and paleontology of the Devonian and Mississippian inliers of southwestern Pennsylvania. In summarizing his work Mr. Laird wrote:

"The Upper Devonian of southwestern Pennsylvania shows two distinct magnafacies, the marine Big Bend into which the non-marine Catskill is tongued from the east and southeast. Traces of two other magnafacies, the Cleveland and the Smethport, are present but are poorly developed. The Big Bend is quite fossiliferous and apparently represents a shallow water environment similar to that exhibited in the same facies development in northwestern Pennsylvania. A poorly developed fauna, possibly in a lithologic facies similar to the Smethport is present in the base of the southwestern Pennsylvania Catskill magnafacies.

"The basal Mississippian regarded previously in part as Upper Devonian shows two facies developments: a limy sandstone or sandy limestone phase (the Marvin Creek limestone of northwestern Pennsylvania is an example) which is present in western Pennsylvania extending eastward to the Allegheny Front, and a shale phase (Riddlesburg shale) east of the Front extending as far as the Broad Top area."

Dr. Earl H. Myers of the Woods Hole Oceanographic Laboratory has received support from the Geological Society of America in completing additional studies of Foraminifera. Present work has to do with the influence of ecological conditions on the distribution and probable rate at which tests of Foraminifera are contributed to marine sediments. The study was begun with collections made in the Java Sea area and is to be continued at the Beaufort Laboratory in North Carolina.

A special report by Dr. Myers dealing with ecologic relationships of Recent and fossil Foraminifera is given as a later section of the present report.

Dr. Fred B. Phleger of Amherst College has continued his work with Foraminifera at the Woods Hole Oceanographic Institution. A report on the vertical distribution of pelagic Foraminifera is given below:

"Study of submarine cores has shown the necessity for more accurate knowledge of the ecology of Foraminifera. The most fundamental problem is the question of where the animals live all or part of their lives. It is known that certain species are pelagic, because they have been collected in plankton tows, and it is assumed that all others are benthonic.

"Most geologists have subconsciously assumed that pelagic Foraminifera live at or very near the surface of the sea. This does not appear logical since other elements of the plankton live throughout the entire water column. It is true, however, that the greatest abundance of plankton is in the surface water layers.

"There are other aspects of the problem of the distribution of pelagic species of Foraminifera. Do the shells in marine bottom samples represent an assemblage which lived in the water directly above the position of the sample? How far are the shells transported by currents before deposition? In interpreting past marine environments by foraminiferal faunas in submarine cores it is essential to know what water layers are being interpreted. Most

of the core work to date has been recognition of climatic changes based largely upon pelagic Foraminifera. If all the forms used in this determination live at or near the surface the problem is a simple one, and the greater the vertical distribution the more complex it becomes.

"Any study of the distribution of pelagic Foraminifera should be from known water depths and should be quantitative if it is to be of any use in solving the problems. Most records of tows are purely qualitative and are from surface water zones. One of the recent exceptions is the work done by the METEOR in equatorial Atlantic waters, reported by Schott.[1/] A series of traverses were made between the African coast and Brazil in the tropical region of the South Atlantic. In the report of the METEOR expedition Schott lists plankton tow records for Foraminifera from 93 stations. The tows were made with a Nansen closing net and the water was sampled at various depths down to 1000 meters. The tows were of uniform time duration, and the total number of specimens of Foraminifera is listed for each sample together with percentage ratios of species. In this region the greatest frequency of pelagic Foraminifera is in water depths of 0 to 100 meters, although significant numbers occur at all depths sampled.

The following analysis of Schott's data clearly shows this:

Depth in meters	No. of tows	Mean no. of specimens per tow
0-100	71	489
100-200	7	8
200-400	13	24
400-600	19	10
600-800	12	11
800-1000	19	28

Globigerinoides sacculifera is the most abundant species in this equatorial region. Globigerina bulloides and G. inflata are found in abundance only in the colder surface waters of the region or in the colder water at considerable depth.

"The quantitative results of these tows are only partially reliable, as Schott realized. The reliability of the results showing the mean numbers of specimens occurring at different depths is directly proportional to the

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1/Schott, W., Die Foraminiferen in den aquatorialen Teil des Atlantischen Ozeans, Wiss. Ergeb. Deutschen Atlantischen Exped. METEOR, 1925-27, Band 3, Teil 3, 1935.

number of tows. A difficulty inherent in the Nansen closing net is that the volume of water strained is unknown. Great variation in the volume of water strained is common, as illustrated by quantitative plankton samplers now in use. No attempt was made to discover which specimens were alive when collected and which were simply empty shells. The empty shells represent specimens which are sinking to the bottom and are of no significance in solving problems of habitat.

"During a short cruise of the ATLANTIS during the summer of 1941 the writer made serial plankton tows at known depths down to 100 meters. These were made with the quantitative plankton sampler developed by Dr. George L. Clarke and Mr. Dean F. Bumpus of the Woods Hole Oceanographic Institution. This device may be opened and closed at known depths, and in addition the volume of water strained is measured.

"One of the difficulties has been in distinguishing living specimens from empty tests. This involves the recognition of protoplasm in the specimen and is very difficult without staining. Certain biological stains can be applied, but decalcification of the specimen is advisable and in most cases necessary. This procedure destroys the test which is most valuable for a paleontologist. At the suggestion of Dr. George P. Child of the Amherst College Biology Department a successful technique for recognizing protoplasm was developed by Mr. W. Gerrish Metcalf, a graduate student at Amherst College. This is the buret test for protein in which the protein containing substance, such as protoplasm, is colored purple. The technique is simple, speedy, and the shells can be preserved for future reference since the purple color shows through the test in all the pelagic specimens so far examined.

"The 1941 tows came from the water over the basin of the North Atlantic south of Georges Bank, where the depth of water ranges from about 3000 to 5000 meters. The greatest concentration of pelagic specimens is in water over the continental slope and ocean basin according to occurrences in bottom samples. The tows were made primarily to discover whether the quantitative plankton samplers could be operated successfully at great depths and whether Foraminifera occurred at such depths. A second and equally important purpose was to use the material collected in a few tows for experiments in technique of preserving and study. No attempt was made to do systematic collecting over a large area.

"Since only six serial tows were made (17 samples) the results are restricted in their significance. It is possible, however, to make several important and interesting observations from the data obtained. The most significant fact is that specimens of Forminifera were present in every sample, at all depths from 75 to 1000 meters. All but three samples contained living specimens. The frequency of living specimens at 1000 meters varied from .5 to 4.6 specimens per cubic meter of water; this is a fairly large population. At one station 4.5 times the number of living specimens per unit volume of water was found at 1000 meters as at 100 meters. It is true that the largest percentage of specimens found in the deep tows

were empty tests, presumably those settling from the upper layers of the water. The data suggest a greater population of Foraminifera at approximately 1000 meters than at approximately 100 meters, although the data are not sufficient for a reliable conclusion.

"Nearly all the specimens in the tows are very small and without exception very thin-shelled. This may have been due to the season of year at which collecting was done. In bottom samples from the same area a large percentage of the specimens of pelagic species are large and heavy-shelled. The greatest percentage of specimens were of Globigerina bulloides with Globigerinoides rubra occurring in significant numbers. Other species found in the tows are Globigerina inflata, G. pachyderma, Globigerinella aequilateris, Globorotalia hirsuta, G. truncatulinoides, G. scitula, and Orbulina universa.

"This is preliminary to a more extensive program of towing for Foraminifera which it is hoped can be undertaken as soon as conditions permit. It is believed that the practical problems of collection and study have been mostly solved."

Dr. Horace G. Richards of the Academy of Natural Sciences of Philadelphia has continued his studies on the Pleistocene mollusks of the East Coast of North America, mentioned in last year's report. Additional field work has been done on the Cretaceous and Tertiary deposits of New Jersey and North Carolina. Reports on the Kirkwood and Raritan formations of New Jersey are completed and awaiting publication, while a general survey of the Coastal Plain of North Carolina is now under way.

Dr. Mary Sears of the Woods Hole Oceanographic Institution has submitted the following report on her current studies of plankton:

"1. Plankton studies off the coast of Peru.-- The so-called, Humboldt or Peruvian current is of particular interest because of the great abundance of life it supports (Good bibliographies:- R. C. Murphy, Oceanic Birds of South America, American Museum of Natural History, 1245 pp., 1936; E. R. Gunther, A report on oceanographical investigations in the Peru coastal current, Discovery Reports, 13:107-276, 1936). Locally, it is of economic importance to learn about the cataclysmic 'crash' periods which occur about every seven years and during which there may be heavy rains, the water temperatures increase markedly, and the guano birds die of starvation. Recently, the Campañia Administradora del Guano completed a three year program for a study of these birds. Since they are almost entirely dependent on anchovies for food, a knowledge of events in the sea is likewise essential. A beginning of such a study started nearly two years ago with the collection of plankton samples and temperatures at North Chincha Island. Then, during the latter part of last year (1941), it was possible to undertake a survey of the entire Pisco Bay area, i.e., of temperatures, salinities, plankton, and anchovies. Unfortunately, the war has curtailed further work along this line, but it is to be hoped that similar observations may be continued over a period of years at some future date.

"2. Annual Fluctuations in Plankton.-- After completing the report (Bigelow and Sears, 1939) on the zooplankton collected by the U. S. Bureau of Fisheries in connection with mackerel investigations, it seemed worthwhile to continue collecting material on a profile across the continental shelf south of Cape Cod to study the fluctuations which occur from year to year, in order, if possible, to discover the reasons for such fluctuations.

"While collections on the continental shelf were of chief concern, collections have also been made in the Slope Water and Sargasso Sea."

Prof. Willis L. Tressler of the University of Maryland is completing a two years study of the seasonal variation of the littoral ostracode fauna of the Solomon's Island region in Chesapeake Bay. Extensive collections have been made over the entire region during two summers, monthly collections being made at three stations during the two year period. Chemical and physical data were taken every three weeks. To date about 20 species of ostracodes have been found.

Prof. Tressler is also engaged in several studies of microplankton organisms in various parts of Chesapeake Bay.

MIDDLE UNITED STATES

Prof. Carl C. Branson of the University of Kentucky has discovered that conodonts are abundant in all formations and members of the Ordovician, Silurian, and Devonian systems in central Kentucky. He states:

"Regardless of lithology, conodonts can be found in all horizons which can be sampled and at all localities. Not a single sample of more than one hundred taken to date has failed to contain conodonts....

"Obviously the above evidence shows that conodonts were free-swimming organisms. They can not have been dependent upon the bottom conditions of the seas, as are worms. They do not show facies variation and recurrence as do all other organisms of the sequence."

Central Kentucky formations of the Ordovician, Silurian, and Devonian age are listed below. Stratigraphic levels from which Professor Branson has obtained conodont faunas are indicated by asterisks.

Devonian
- *New Albany sh.
- *Boyle ls.
  - *Casey ls.
  - *Kiddville layer

Silurian
- *Crab Orchard sh.
- *Brassfield ls.

Ordovician
* Richmond
Saluda - not present
*Liberty
*Waynesville
*Arnheim
*Oregonia
*Sunset
*Maysville
Mount Auburn - not sampled
Corryville - not sampled
*Tate
*Fairmont
Mount Hope - not sampled
*Eden
*Garrard ss.
*Million
Fulton - not sampled
*Cynthiana
*Rogers Gap
Gratz - not sampled
Bromley - not sampled
*Greendale
pre-Greendale - not sampled
Perryville - not sampled
*Woodburn
*Brannon
*Benson
*Jessamine
*Hermitage
*Curdsville
*Tyrone
*Oregon
*Camp Nelson

Dr. Josiah Bridge of the U. S. Geological Survey and Dr. Virgil E. Barnes of the Bureau of Economic Geology, Texas have submitted the following brief report of facies changes in the Cambrian of central Texas.

"In studying the Cambrian formations of the Llano uplift of Texas, a number of interesting facies gradations have been found. These facies changes are both vertical and lateral and involve transitions from sandstone to limestone, without the intervention of shale; shale to limestone; limestone of one type to limestone of an entirely different type. A special case in the last mentioned class is the presence of reefs, or bioherms, in limestone. In most cases the faunas are very closely related to the type of rock containing them. Some beds are abundantly fossiliferous, while in others of the same age but of a different lithology, fossils are scarce or of entirely different types. Although most of the fossils seem to be very definitely associated with a certain environment, some species are cosmopolitan and apparently were able to live under almost all conditions of

sedimentation present in the area. These species have been extremely useful in making correlations between different lithologic types within the Llano uplift. Conversely, it has been noted that certain forms which are characteristic of highly specialized facies, tend to appear in other parts of North America, when a similar environment developed at about the same geologic time." (An abstract dealing with certain aspects of this work was published in the Bulletin of the Geological Society of America, vol. 52, p. 1996, 1941).

Mr. Heinz A. Lowenstam, paleontologist at the Illinois State Museum is engaged in a study of the Niagaran faunas of northeastern Illinois and nearby areas in Iowa, Missouri, Kentucky, and Indiana. He states that field work has revealed the presence of a considerable number of faunal elements thought to be restricted to the so-called southern faunal province. He has also found a number of previously unrecorded forms that are closely related to or identical with those of the Anglo-Scandinavian basin. Various biotopes will be described. Faunal migration routes are being studied. The first of a series of papers to be published shortly by the Illinois State Museum will describe the sponge faunas and the enclosing cherts which Mr. Lowenstam believes are sponge derived. A second paper will deal with crinoids.

Mr. Thomas G. Payne now at the University of Kansas has submitted the following abstract of a thesis on the Middle Devonian recently completed at the University of Chicago:

"Stratigraphical analysis and environmental reconstruction.-- Inasmuch as coexisting organisms and sediments are governed by the same set of environmental factors, they are environmentally interrelated, and study of the ecology of organisms must go hand in hand with study of the ecology of sediments. Prerequisite to the analysis and reconstruction of an ancient environmental setting is a thorough description of the character and genesis of the sedimentary assemblage. Too often, paleontologists attempting to restore an ancient environment have had an inadequate understanding of the sedimentary aggregate and have based their environmental interpretations primarily on analogies between Recent and fossil plants and animals and communities or assemblages. A paleoecologist must delve deeply into the field of sedimentary petrology. This paper outlines and describes a petrographic and petrogenetic approach to the study of marine environments.

"A plan is presented for comprehensive study and analysis of a sedimentary deposit, including petrographic and paleontologic description of the fundamental attributes, properties, and structures of the sediment and its life assemblage and the interpretive description of genesis of the deposit. The genetic phase embraces evaluation of the environmental factors, ecologic and geographic, and the dynamic processes and resultants involved in sedimentary petrogenesis. Methods, principles, and concepts are illustrated throughout the paper by the use of the crinoidal phase (Croneis' Bed 9) of the Grand Tower limestone of Ste. Genevieve County, southeastern Missouri, as a test case.

"The paper presents an outline classification of the ecologic factors, inherent in aqueous environments, which must be evaluated in environmental reconstruction. These factors influence to different degrees the existence of organisms and sedimentary components anywhere on the earth-water interface. Other factors, such as depth of water, are of indirect influence and are treated separately as geographic factors. The ecologic factors are as follows:

I. Factors Pertaining to the Substratum
  A. Composition and textural character
  B. Inclination
II. Factors Operative on Substratum
  A. Movement (transportation) of sediment on substratum
    1. Individual
    2. Collective
  B. Character and activities of benthonic life (biotic factors)
III. Factors Pertaining to the Medium
  A. Motion of the medium
    1. Agitation (turbulence)
    2. Bottom currents (velocity)
  B. Dissolved gas content
  C. Salinity
  D. Character of suspension load (composition, grain size, volume, turbidity, etc.)
  E. Temperature
  F. Light intensity
  G. Hydrostatic pressure
IV. Factors Operative in Medium Above Substratum
  A. Movement (transportation) of suspended sediment
  B. Character and activities of pelagic life (biotic factors)"

WESTERN UNITED STATES

Mr. J. Wyatt Durham who gave a preliminary report on his study of the Bathymetric Distribution of Living gastropod genera in last year's report (also published in Bull. Geol. Soc. Amer., vol. 52, pp. 1980-81, 1941) has submitted the following statement regarding the present status of the project.

"The project has been continued through the last year with N. Y. A. help in steadily diminishing amounts. Because of the lack of help and the critical world situation it was decided to conclude the work and summarize it. Since then (December, 1941), the median, maximum and minimum depth ranges for about half the genera has been determined. The data for each genus has been divided into three temperature zones based upon the geographic distribution of the records with regard to the winter isotherms. The zones are: (1) below 5 degrees Centigrade; (2) 5 to 20 degrees Centigrade; (3) over 20 degrees Centigrade.

"Inasmuch as the work is strictly a compilation, it is evident that there are numerous sources of error and particularly from varying standards of toxonomy in the source works. Nevertheless it is readily apparent that some genera are strictly limited in their bathymetric distribution.

"It is hoped that the summarization of the data will be finished in the next few months and the data published shortly thereafter."

Mr. Durham has also reported on a study of the Recent corals of the Gulf of California and the North Pacific Coast, as follows:

"Of a possible 25 species in the Gulf of California fauna and 12 species in the North Pacific coastal fauna there is possibly one (a species of Paracyathus) common to the two areas, the boundary between the two provinces apparently falling at Cape San Lucas or near to it. On the contrary the Gulf of California fauna is much more closely related to the Panamic fauna, many of the species extending south to the Bay of Panama.

"Unfortunately bathymetric and thermal data for many of the corals is not available but thermal data from the cruise of the 'E. W. Scripps' in February and March, 1939 make it possible to estimate the lower temperature limits of the Gulf of California occurrences with some degree of accuracy.

"The following*table gives the distribution and the depth and temperature ranges in so far as known of the Gulf of California and North Pacific coastal species."

*(see next page)

"Balanophyllia elegans, the common littoral species, is represented by greatly different individuals in the northern and southern parts of its range. Those in the south having much heavier and coarser skeletal elements. Apparently Paracyathus stearnsii has a discontinuous distribution, only occurring in the north in local areas where the temperature is much warmer than normal.

"Steinbeck and Ricketts have recently reported a true reef composed of Pocillopora within the Gulf, and apparently reefs of Porites were noted around Carmen and Coronados Islands by the present author but not examined. Porites reefs occur in the Pliocene and Pleistocene of Carmen and Coronados Islands, with late Pliocene reef in Marquer Bay, Carmen Island, being of large size. It is noteworthy that all reefs examined or reported are monospecific, composed of either Porites californica or Pocillopora robusta.

"During the earlier Pleistocene both Pocillopora and Stephanaria ranged northward to the Carmen-Coronados Island area, and Porites extended its range around Cape San Lucas to Magdalena Bay, indicating warmer temperatures than at present.

	Distribution		Depth	Temperature (Centigrade)
	North Pacific Coast	Gulf of California-Panama		
Astrangia insignifica Nomland		north to 31° lat.	lit.* to 20 f.	15° and above
Astrangia Sp.	32-33° lat. and south?		lit.	
Astrangia (Coenangia) sp.		north to 28° lat.	"shallow"	15° and above
Balanophyllia elegans Verrill	33-50° lat.		lit.	
Balanophyllia sp.	27-28° lat.		"dredged"	
Balanophyllia sp.		28° 44' lat.	73 m.*	13°
Caryophyllia spp.	36-61° lat.		0-218 f.*	
Coenocyathus bowersi Vaughan	34-37° lat.		"shallow" to 30 f.	9.5 to 12.5° and higher
Cycloseris elegans (Verrill)		north to 25° lat.	"shallow"	17° and above
Cycloseris (Diaseris) sp.		26° lat.	31 m.	16°
Dendrophyllia tenuilamellosa Verrill		0-25°	"shallow"	17° and above
Dendrophyllia oldroydi	33° 30' lat.		100 to 200 f.	
Dendrophyllia sp.	27° 52' lat.		23 f.	
Endopachys sp.		23° lat.	20-50 (?) f.	19-20°
Pavona gigantea Verrill		north to 26° lat.	7 f.	16° and above
Paracyathus sp.		28° 44' lat.	73 m.	13°
Paracyathus sp.	33° 30' lat.		200 f.	
Paracyathus stearnsii Verrill	33-53° lat.		30-50 f.	16.2°(53° lat.)
Paracyathus caltha Verrill	34-37° lat.		20 f.	
Pocillopora spp.		north to 25°	"shallow"	17° and above
Porites spp.		north to 29° 35' lat.	low tide "shallow"	15° and above
Stephanaria stellata Verrill		north to 25° lat.	"shallow"	17° and above
Montipora fragosa Verrill		25° (?) lat.		17° and above

* lit. - littoral
f. - fathoms
m. - meters

Mackenzie Gordon Jr. of the U. S. Geological Survey has reported upon a study of Monterey Bay, California, as follows:

"Allyn G. Smith, Research Associate on Conchology of the California Academy of Sciences, and I are prearing, at the request of the Academy, a report tentatively entitled, 'The Recent Marine Brachiopods and Mollusks of the Monterey Bay Region, California'. The Monterey Bay region, in this case, includes that portion of the California coast lying between Pigeon Point at the north and Point Sur at the south. Within this area is found almost every combination of ecologic conditions known to a section of coast lying in the temperate zone.

"The report is based upon collecting notes made by Mr. Smith, the senior author, in the Monterey region between the years 1912 and 1937, and by me between 1920 and 1937, on further records in private and museum collections in California and in the collections of the U. S. National Museum, and on an exhaustive search of the literature. The nudibranch mollusks are included in the report thanks to a list supplied by Dr. F. M. MacFarland of the California Academy of Sciences, as well as the cephalopods through a similar list from Mr. S. Stillman Berry of Redlands, California.

"Following introductory remarks on the history of collecting, ecologic aspects, commercial aspects, notes on mollusk poisoning, etc., the main portion of the paper is in the form of an annotated check list giving all available data on the bathymetric range and ecologic habitat of the species, and occasional taxonomic notes on species which local collectors have found difficulty in identifying. We have managed to assemble records of nearly 800 species from this area and to check the identification of perhaps 95% of them. Some of these records are discarded as misidentifications and others are viewed with suspicion when the material was unavailable for checking, when there appeared to be a possibility of a collector's error in locality, or when the material might have been adventitious. We still retain as constituting, in our opinion, valid records of 7 species of brachiopods and slightly over 700 species of mollusks. We also append a list of approximately 60 additional mollusks which have been recorded from localities north and south of the region but have not yet been collected within it. This is an unusually large fauna for a comparatively small area lying so far north of the equator.

"Of the molluscan species, 18 are new and are described at the end of the report. At present the paper is undergoing minor final revision prior to being submitted to the Academy for publication."

Prof. J. Harlan Johnson has reported as follows on his current studies of fossil algae and associated organisms:

"1. We are preparing a report on the algae and related organisms from the Upper Leadville limestone (Mississippian) of the Glenwood Springs region of Colorado. In this study, we have endeavored not only to note the algae but have tried to recognize and classify the various organic fragments a

associated with them in the hope that the information will give a better picture of the environment in which the algae occurred. This study has been made with the assistance of the U. S. Geological Survey. We hope to have the report finished by June. Eventually, it will probably be published by the Geological Society of America.

"2. During the summer of 1940, we collected considerable material from the various Pennsylvanian and Lower Permian limestones of Kansas under the auspices of the Kansas Geological Survey. In 1941, we obtained a research grant from the G. S. A. to complete studies of this material. It includes about 1,000 specimens from nearly 200 localities. The laboratory work is nearly completed and I hope to have the report finished by the end of the year. It will be submitted to the G. S. A. for publication. In this study, also, we have endeavored to identify all associated organic fragments to assist in the ecological picture."

Mr. Stanislav Kříž of Princeton, New Jersey, has submitted the following notes dealing with an ecological study that he is carrying on in the Sierra Diablo, West Texas:

"My interests right now are centered around several bioherms developed in the Mid-Permian Bone Springs formation, and marvelously exposed in the walls of Apache Canyon along the northeast rim of the Diablo Plateau.

"Although I shall be engaged in some stratigraphical work and possibly large scale mapping of facies, I feel quite confident, that my main contribution may be anticipated as a paleo-ecological study of the bioherms mentioned above. So far, the detailed stratigraphic relationships are not clear to me. Much of the ideas are mere speculations based on previous work of Dr. P. B. King and especially Dr. J. B. Knight, under whose direction my work at Princeton is being done.

"It appears, as if the oldest one of the bioherms in consideration was formed at a point, where the otherwise almost horizontal erosion surface representing a local (?) unconformity between the Hueco and Bone Springs formation begins to dip sharply seaward. Thus it seems quite possible, that the bioherm represents a wave resisting structure, and deserves to be called a reef."

Mr. M. L. Natland of the Richfield Oil Corporation in reporting on ecologic work being done in the West stated that no substantial amount of work had yet been done on the long core samples from the Gulf of California, and therefore no report could be made at that time. Two other studies dealing with ecologic work were outlined by Mr. Natland, as follows:

"Dr. Lore David, of the California Institute of Technology, Pasadena, California, has been studying fishes for several years. Recently she has turned her attention to the study of Recent and fossil scales in the Southern California region. With the aid of Recent scales from known fishes, she has been able to classify many of the scales found in the Tertiary

sediments of this region. As with other groups of sea animals, fishes live in their own ecologic niche. There is a large group of tide-pool and near-shore fish, especially certain perch and bass, which seldom if ever venture from this habitat. There are intermediate-depth fish and also those which live at abyssal depths of one thousand fathoms or more, such as those belonging to the Rat tail group. There are some which live only in warm surface-waters while others prefer cold surface-waters. Fish scales are numerous and well-preserved throughout most of the California Tertiary, and their classification should reveal a wealth of data as to the depositional environment of these sediments. However, inferences as to the fossil environment suggested by fishes should be looked on with caution, for it is possible to have scales transported from their place of development. Fishes die and are seldom left to disintegrate without being eaten by other fish, and the scales are not always completely destroyed in the fish's intestinal tract but are passed through to be deposited far away from the place where the fish was eaten. There is probably greater chance of scales from shallow-water fish being transported to deeper water than for scales of abyssal fish being transported to shallow water. Therefore, if abyssal fish scales are present in sediments, it would seem quite safe to conclude that the sediments were laid down in abyssal waters. It is hoped that Doctor David can continue this work long enough to show its practical value."

"W. Thomas Rothwell Jr., of the Richfield Oil Corporation, Long Beach, California, has presented the results of his paleoecologic studies of the Saucesian and Zemorrian stages of Southern California, at the April meeting of the Geological Society of America.

"One of the interesting conclusions of his study is that the siltstone exposed along the west bank of the Cuyama river near its juncture with the Huasna river in San Louis Obispo County is not Zemorrian, as reported by Schenck and Kleinpell, but is deep-water Saucesian. The foram fauna in the type Saucesian section exposed in Los Sauces creek near Rincón Point, Ventura County, California, is made up of Siphogenerina, Robulus, Nonion costiferum Cushman, and Uvigerina. These forms suggest a depositional environment of between 1,000 and 3,000 feet of water, whereas the probable depth of the ocean in the vicinity of the Cuyama river section was 6,000 feet or deeper, as suggested by such deep-water species as Bulimina cf. rostrata Brady, and Pullenia bulloides d'Orbigny, together with numerous others. In spite of the dissimilar character of these faunas, Mr. Rothwell is reasonably certain that they are synchronous in age, as the superjacent beds in both sections are of Relizian age while the subjacent beds are both Zemorrian in age; also, they are lithologically similar. Here we have a clear example of two dissimilar faunas being of the same age."

Mr. Frank A. Pitelka of the Department of Zoology, University of California, has submitted a brief report on ecological studies of intertidal flats in California.

"A study of intertidal flats along the central Californian coast was begun in May and June, 1941. The chief site of field work has been the

northern end of Tomales Bay, Marin County, California. Supplementary and comparative observations have been made in Bodega Lagoon, Stemple Creek Estuary (both in Sonoma County), and Bolinas Bay (Marin County). Current circumstances have made it necessary to suspend further field work.

"In this investigation, an attempt is being made to determine the ecologic distribution of the various mud and sand-flat forms, their community organization, and the successional trends among the various communities. The particular features of the mud flats and adjoining dunes at the upper end of Tomales Bay are such that fairly rapid and striking changes have taken place within periods of a few years. Special attention has been paid to the analysis of factors which operate in these changes. Briefly, the present picture, as regards the Tomales Bay flats, is as follows:

"The physiographic dynamics of these flats illustrate a tension zone between agencies tending to develop a sublittoral, bottom habitat and those tending to develop a terrestrial habitat. The chief factors involved are tidal currents, wind, waves, fresh water streams, and biotic reactions; each factor, influenced in turn by climatographic agents, operates in both directions but in different ways and at different rates.

"The combined action of these factors influences the topographic character of the intertidal zone. On a given transect, the same factors determine variation in exposure, nature of substratum, and drainage. Such variation will effect a zonal distribution of the fauna according to the intertidal level to which particular organisms are adapted. At different parts of the same intertidal level, the fauna may differ according to differing influences of the same factors. But all situations and conditions are more or less transitory; the continued action of the several agencies mentioned above brings about habitat changes and shifts in the biota. Much evidence of comparatively rapid succession among the predominant animal aggregations may be seen progressing towards either terrestrial or marine habitats (Pitelka and Paulson, Bull. Ecol. Soc. America, vol. 22, 39-40, 1941.)

"We have received invaluable assistance from numerous specialists in the identification of species. A number of new locality records involving extensions of ranges have been accumulated, and several new species have been recognized. To date approximately 150 intertidal forms inhabiting sand, mud, and associated algal beds have been recorded; of these 23% are molluscs, 28% are polychaetes, the two predominant groups."

Prof. Francis P. Shepard of the University of Illinois has continued his varied oceanographic studies of the California coast. References to material published by Shepard and his associates is given elsewhere in this report. Jointly with R. S. Dietz and K. O. Emery he has prepared a report on Phosphorite Deposits on the sea floor that is scheduled to appear in an early issue of the bulletin of the Geological Society of America.

A paper by Denis L. Fox and Lloyd J. Anderson, "Pigments from marine muds," Nat. Acad. Sci. Proc., vol. 27, pp. 333-336, July 1941, should be noticed here. The résumé (p. 336) is as follows:

"Résumé.-- The demonstration of numerous chlorophyll derivatives and carotenoids in ancient marine deposits is thought-provoking. Chlorophylls are known to undergo advanced biochemical changes in animal organisms, while carotenoids found in feces may retain their complete integrity. The absence of chlorophylls themselves in the presence of a suspected protochlorophyll and other simpler degradation products leads to a consideration of possible biochemical changes wrought by non-chlorophyllous microorganisms, and emphasizes the questions regarding interrelationships between chlorophylls and protochlorophyll in green plants.2/

"The encountering of relatively rich deposits of numerous carotenoids also bears on the question of metabolic activities in marine muds. Does the preponderance of carotene-like pigments over xanthophylls in gulf [of California] muds actually indicate an excess of fungal and bacterial over algal remains, or have isomerization and other chemical changes taken place, with or without biological intervention, to alter so extensively the situation encountered in marine algae?

"The question of synthesis of carotenoids by bacteria and fungi isolated from marine muds is being investigated, and problems involving possible changes in chlorophyll and certain carotenoids by such organisms are being undertaken.

"The encountering of a fluorescent, non-carotenoid pigment in both a sample of crude petroleum and a marine mud core (accompanied in the latter by a green pigment, supposedly resulting from chlorophyll degradation) lays emphasis upon the importance of continuing investigations on the biogenic origins of petroleum."

OUTSIDE THE UNITED STATES

Mr. Gilberto Botero at the University of Chicago, according to Professor Cary Croneis, is preparing a thesis on certain early Tertiary faunas from the Cauca area of Colombia in which ecological considerations play an important part.

M. L. Natland, of the Richfield Oil Corporation, Long Beach, California, has completed his work on the foraminifera occurring in a large number of bottom samples collected from off the west coast of Panama. The results of this work will be published in the Bulletin of the Scripps Institution of Oceanography, in the near future. Mr. Natland stated: "This study should add considerably to our knowledge of the depositional environment of the Later Tertiary of Mexico, Central America, and the northwestern portion of South America. The fauna of the Charco Azul formation of Panama, recently

2/ Rothemund, F., Cold Spring Harbor Monogr. Quart. Biol., 3, 71-79 (1935).

described by H. N. Coryell and R. W. Mossman (Jour. Paleo., vol. 16, pp. 233-246, 1942) is represented off Panama in depths of water between 900 and 1,500 feet. It seems quite certain, barring changes in requirements of foraminifera since Pliocene time, that this fauna was not laid down in water deeper than 1,500 feet, because off Panama at this depth a large number of species make their first appearance, and these species were not among those listed in the publication. A similar fauna is present in the section exposed on Carmen Island in the Gulf of California. However, the Carmen Island fauna contains many species suggestive of water deeper than 1,500 feet and shallower than 3,000 feet.

"An interesting set of samples has just arrived from Alaskan waters. The foraminiferal fauna in some of the deeper samples is not composed of the species one would expect. The deepest sample from 592 feet, with a bottom temperature of 5.8° C., was made up almost entirely of specimens of Nonion and Elphidium, and with rare Cassidulina limbata Cushman and Hughes. It seems that Elphidium is confined to neither shallow nor warm water; that certain species of the genus can live as deep as 100 fathoms in water as cold as 5.8° C.

"I hope to obtain a sufficient number of samples from Alaskan waters to determine the bathymetric and temperature range of Alaskan fauna."

Dr. Horace G. Richards made a collecting trip to Baja California, Mexico during the summer of 1941. Numerous mollusks, both fossil and Recent, were obtained, particularly from the region of Concepción Bay. A report discussing the ecological conditions of the region is being prepared.

RECENTLY PUBLISHED PAPERS

PALEOECOLOGY

Bradley, W. H. and others, Geology and biology of North Atlantic deep-sea cores, parts 4-9, U. S. Geol. Survey, Prof. Paper 196. Parts 1-3 of this study were cited in last year's report. The remaining portions have appeared subsequently, as follows:

Part 4, Ostracoda by Willis L. Tressler, pp. 95-106, 1941
5, Mollusca by Harold A. Rehder, pp. 107-110, 1942
6, Echinodermata by Austin H. Clark, pp. 111-118, 1942
7, Miscellaneous fossils and significance of Faunal Distribution by Lloyd G. Henbest, pp. 119-130, 1942
8, Organic matter content by P. D. Trask, H. W. Patnode, J. L. Stimson and J. R. Gay, pp. 135-149, 1942.
9, Selenium content and chemical analyses by Glen Edgington and H. G. Byers, pp. 151-156, 1942.

Cooper, Byron N., Athens equivalents northwest of Clinch Mountain southwest Virginia (abstract), Bull. Geol. Soc. Amer., vol. 52, pp. 1892-1893, 1941.

Cooper, G. Arthur, Facies relations of the Middle Devonian (Hamilton group) along the Catskill Front, (abstract), Bull. Geol. Soc. Amer., vol. 52, p. 1893, 1941. Paper to be published in full at later date.

Emery, K. O., Transportation of rock particles by sea-mammals, Jour. Sed. Pet., vol. II, pp. 92-93, 1941.

Emery, K. O., and Shepard, F. P., Lithology of the sea floor off southern California (abstract), Bull. Geol. Soc. Amer., vol. 52, pp. 1899-1900, 1941.

Emery, K. O., and Tschudy, R. H., Transportation of rock and kelp. Bull. Geol. Soc. Amer., vol. 52, pp. 855-862, 1941.

Gekker, R. F., (On the organization of research in paleobiology, Probl. Ecol. and Biocenol. Leningrad, vol. 1, pp. 43-55, 1934). (In Russian, German summary).
A discussion of the methods and aims of Russian paleobiology and a review of the work of the Paleozoological Institute of the Academy of Science, which includes the study of the life and habits of extinct forms and the study of environmental conditions and interrelations of these organisms. Reconstruction of the biocenoses and the tracing of their changes and development through previous and subsequent geological periods is carried out.

Johnson, J. Harlan, Permian lime-secreting algae from the Guadalupe Mountains, New Mexico, Bull. Geol. Soc. Amer., vol. 53, pp. 195-226, 1942.

King, Philip B., Permian of West Texas and southeastern New Mexico, Bull. Amer. Assoc. Pet. Geol., vol. 26, pp. 535-763, 1942.

Knox, Arthur S., The use of bromoform in the separation of non-calcareous microfossils, Science, vol. 95, pp. 307-308, 1942.

Laudon, L. R., and Bowsher, A. L., Mississippian formations of Sacramento Mountains, New Mexico, Bull. Amer. Assoc. Pet. Geol., vol. 25, pp. 2107-2160, 1941.

Popovici, Zaharia, Massensterben von Upogebia littoralis an der Westkuste des schwarzen Merres, Acad. Roumaine, Bull. Sect. Sci., vol. 22, No. 9, pp. 420-422, 1940.
Thousands of this decapod and two mollusks were cast on the beach by storms, with a rapid drop in water temperature a contributing factor. An example of catastrophic death of animals.

Ruedemann, Rudolph, Notes on Ordovician plankton and radiolarian chert of New York, New York State Museum Bulletin, No. 327, pp. 45-71, 1942.

Shepard, Francis P., Nondepositional physiographic environments off the California Coast, Bull. Geol. Soc. Amer., vol. 52, pp. 1869-1886, 1941.

Shepard, Francis P., and Emery, K. O., Submarine topography off the California Coast, Geol. Soc. Amer., Spl. Paper no. 31, 1941.

Stark, J. R., and Dapples, E. C., Near shore coral lagoon sediments from Raiatea, Society Islands, Jour. Sed. Pet., vol. II, pp. 21-27, 1941.

Sverdrup, H. U., The Pacific Ocean, Science, vol. 94, pp. 287-293, 1941.

Zenkevich, L. A., (Achievements in the sea-fauna study of the USSR for twenty years, 1937). (In Russian).
There has been unprecedented growth of activity in this sphere since 1917. Improvements in method and technique were made in collecting organisms and subsequent treatment of plankton. Thirty per cent salt solution for preserving plankton was found superior to alcohol and formalin. Important data have been collected for understanding the origin and distribution of the polar sea fauna. Evidence for the support of the theory of bipolarity was obtained. The temperature of the Barents Sea was found to be rising with resulting changes in fauna. New grouping was given to the fauna of the Aral, Caspian, and Black Sea. The original autochthonous fauna is best preserved in the Caspian Sea; little is left in the Aral Sea, the Black Sea and the Sea of Azov it is supplanted by a Mediterranean fauna.

PLANTS

Chapman, V. J., Studies in salt marsh ecology. Section VIII, Jour. Ecol., vol. 29, pp. 69-82, 1941.
This paper is concerned with the Norfolk salt marsh succession and gives a general account of British salt marshes.

Davis, John H., Jr., The ecology and geologic role of mangroves in Florida, Carnegie Inst. Washington, Pub. 517. Papers from Tortugas Laboratory, vol. 32, pp. 303-412, 1940.
In this study, which occupied 5 field seasons around the Florida Coast, the author found that in general the succession of mangrove communities from offshore sites inundated by tides to fresh-water or upland situations inland, is as follows, as graphically indicated in his figure 3, page 324:
(1) A pioneer stage dominated by red mangrove (Rhizophora mangle) with which are associated a number of marine algae and some aquatic seed plants. The mangrove seeds take root in (a) siliceous sands, (b) calcareous sands, and (c) calcareous marl muds. This stage matures into a forest swamp (2) composed almost entirely of mangroves with tangled prop roots that act both as anchors for the plants and as traps to catch sediments and other debris. The third community (3) is composed of open stands of the black mangrove (Avicennia nitida) interspersed with

other salt-marsh associates. The white mangrove (Laguncularia racemosa) may occur in both zones (2) and (3). Zone (3) may be inundated by every average tide over its outer part, but its inner part may be free from such action. (4) A transitional zone, seldom, if ever, flooded, between the mangrove communities and the inland vegetation, is composed of buttonwood (Conocarpus erecta) and many other hardwoods. (5) A tropical or subtropical forest composed of pines, palms, and hardwoods, which is the climax of the region. Some of the areas found in zone (5) display the hammock type of forest topography.

Associated with this succession of mangrove communities is a large aquatic and aerial fauna that makes some contribution to the sediments accumulating in the swamps in the form of sands, marls, and peats. The ultimate result of the growth of the mangrove communities is the formation of soils at ever higher levels, and the extension of the coasts. It may thus be possible to utilize mangrove plantings in building up and protecting coastal soils. The peats associated with the mangrove succession can usually be distinguished by microscopic study of the contained plant fragments, and in some cases by differences in color.

Mangrove leaves have been identified from early Tertiary coastal plain sediments in areas adjacent to Florida. The author does not believe, however, that the Florida mangroves have occupied the present littoral belt for a long time because great coastal changes have taken place there. If, however, deposits of pre-Recent mangroves are found they may prove of paleontological significance. Mangrove communities may have formed peat beds of sufficient thickness to be preserved as coal beds. (Roland W. Brown).

Graham, Herbert W., An oceanographic consideration of the dinoflagellate genus Ceratium, Ecol. Monographs, vol. II, No. 1, pp. 99-116, 1941. The species of Ceratium taken by the "Carnegie" were studied in relation to environmental conditions. They were not affected by salinity variations occurring in the open ocean, but were separated into three main categories on the basis of temperature: tropical, subpolar, and cosmopolitan. The fact that eight species were found only in the Pacific and no species was confined to the Atlantic suggests that tropical species of the Atlantic find ready access to the Pacific via the Indian Ocean but that Pacific species are not carried to the Atlantic because of current and other environmental conditions.

Kitching, J. A., Studies in sublittoral ecology, III Laminaria forest on the west coast of Scotland; a study of zonation in relation to wave action and illumination, Biol. Bull., vol. 180, pp. 324-337, 1941.

Sears, Mary, Notes on the phytoplankton on Georges Bank in 1940: Jour. Marine Research, vol. 4, no. 3, pp. 247-257, 1941.

Steenis, C. G. G. J. van, Kustaanwas en mangrove (Coast extension and mangrove), Natuurwetenschap. Tijdschr. Nederland, Indie, vol. 101, pp. 82-85, 1941.
The author concludes from observations in the Dutch East Indies that the mangrove will grow only in places where mud silting takes place under natural conditions; that it does not initiate the process and cannot be used for protection of the coast against erosion.

Wood, Alan, "Algal Dust" and the finer-grained varieties of Carboniferous limestone, Geol. Mag., vol. 78, No. 3, pp. 192-200, 1941.

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Trueman describes methods of determining within certain limits of accuracy the weight, volume, and buoyancy of cephalopod shells and discusses the development of their body-chamber. From data thus assembled he concludes (1) that the relative volumes of the air-chambers and body-chambers can be estimated in any complete specimens, (2) that the length of the body-chamber tends to be similar in ammonites of similar shape, (3) that the ratio of the volume of the air-chambers to the body-chambers is generally about 1 to 2 or 1 to 3, (4) that the length of the body-chamber is related to the total length of the ammonite cone, (5) and that the ratio of air-chamber to body-chamber remains nearly constant during the development of individual ammonites. He estimates that many ammonites had a mean density about the same as sea-water, but that some were much lighter than sea-water, and were presumably planktonic, and that others were much heavier than seawater and were presumably benthonic. He suggests that many ammonites rested with their apertures turned up from the sea floor, but that others were capable of assuming various attitudes. (Ralph W. Imlay).

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Patterson, Joseph M., Halymenites, a marine sandstone indicator: Jour. Paleo., vol. 16, pp. 271-273, 1942.

Ruedemann, Rudolph, Cambrian and Ordovician Fossils, New York State Museum Bulletin, No. 327, pp. 19-29, 1942. Problematical fossils, possibly algae, are described; also included is an Ordovician Oldhamia, supposedly a worm trail, an epiplanktonic sponge, a new graptolite, and some eurypterids.

Scott, Harold W., Conodont assemblages from the Heath formation Montana, Jour. Paleo., vol. 16, pp. 293-300, 1942.

Vokes, H. E., Fossil imprints of unknown origin: Amer. Jour. Sci., vol. 239, pp. 451-453, 1941.
This paper describes very unusual stellate imprints from near Billings, Montana. More recent field work by Barnum Brown shows that the imprints occur only in the Telegraph Creek Series below the Eagle Sandstone. They are now known from 3 localities in Montana. A detailed report will be published during 1942.
John B. Reeside, Jr. of the U. S. Geological Survey has called attention to similar fossils from near Cody, Wyoming, and expresses the opinion that they may be imprints of one of the Stauromedusae.

ECOLOGY OF DIATOMS

by

Kenneth E. Lohman

Gilbert, J. Y., of the Scripps Institution of Oceanography, has found, according to H. U. Sverdrup, Director, that only three diatom forms can be identified in the sediments of the Gulf of California. These are: Thalassiothrix longissima, Coscinodiscus sp., and Pseudoeunotia doliolus. All three forms have thick frustules. In water samples taken at depths greater than 1000 meters empty frustules of the same forms completely dominated.

Patrick, Ruth, A study of diatoms from Linsley Pond. -- in press. (Presumably as a chapter of a series entitled "Studies of Connecticut Lake sediments" appearing in the American Journal of Science.)

AUTHOR'S ABSTRACT: This study is based upon diatoms secured from various profiles as well as on recent samples taken from Linsley Pond. The purpose of this study was to determine the various stages in the lake's development. Chemical analyses of the sediments from the profiles were also made. The evidence from the diatom floras, which was supported by the chemical analyses, indicates that in the beginning the lake was oligotrophic. Early in its history it became eutrophic and remained eutrophic to the present time. This eutrophic period divides itself roughly into three parts. An early part in which conditions were ideal for diatom growth. A middle part which was not as conducive to diatom growth. This period existed until toward the end of the profiles. A third period in which conditions were better suited to diatom growth. In the very recent past there has been a great change in many of the species which flourish in the lake. This may be due to the fact that during the last hundred years the banks of the lake have been opened to the practice of agriculturists.

Doctor Patrick is now making a study of the diatoms from the various types of lakes in the Pocono plateau and surrounding region. These lakes are also being studied by Edmondson and Hutchinson from a chemical standpoint and by Myers as to their rotifer faunas.

Lohman, K. E., Pliocene Diatoms of the Santa Maria District, California. This study probably will not be entirely completed until after the emergency is over but a preliminary report containing correlations between measured sections and some ecological inferences will probably be completed by July 1 of this year (1942).

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Hustedt, Friedrich, Die Diatomeenflora des Küstengebeites der Nordsee vom Dollart bis zur Elbemündung: Abh. Nat. Ver. Bremen, Band 31, Heft 3, pp. 571-677, 123 text figs., 1939.
An excellent ecological study of 448 species and varieties (50 of which are described as new) of diatoms collected from 59 localities along the coast of the North Sea. The introduction of fresh-water and brackish-water species into the marine environment at the mouths of rivers is discussed at some length. Each of the 448 species of marine, brackish-water, and fresh-water diatoms is discussed separately and, in a 10 page summary at the end of the paper, a number of floras typical of specific environments are listed and some generalizations are made regarding ecologic extrapolations from living floras to those found in sediments.

The following papers by Joaquin Frenguelli of the Museum at the National University of La Plata, Argentina, have been selected from a long list of papers by Dr. Frenguelli because they contain considerable ecologic data:

Frenguelli, Joaquin, Diatomeas del Querandinense Estuariano del Rio Matanza en Buenos Aires: Revista del Museo de La Plata (Nueva Serie), Tomo 1, Sección Palentológia, pp. 291-314, pl. 1, 1938.

Frenguelli, Joaquin, Diatomeas de la Bahia de San Blas (Provincia de Buenos Aires): Revista del Museo de La Plata (Nueva Serie) Tomo 1, Sección Botanica, pp. 251-337, pl. 1-7, 1938.

Frenguelli, Joaquin, Diatomeas del Golfo de San Matias (Rio Negro): Revista del Museo de La Plata (Nueva Serie), Tomo 2, Sección Botanica, pp. 201-226, pl. 1-2, 1939.

NON-MARINE

Frenguelli, Joaquin, Diatomeas del Rio de La Plata: Revista del Museo de La Plata (Nueva Serie), Tomo 3, Sección Botanica, pp. 213-334, pl. 1-7, 1941.

Brinley, Floyd J., and Katzin, Leonard J., Distribution of stream plankton in the Ohio River system: Am. Mid. Nat. vol. 27, No. 1, pp. 177-190, 1942.

Dewey, Edward S. Jr., Studies on Connecticut lake sediments, III, The Biostratonomy of Linsley Pond: Am. Jour. Sci., vol. 240, no. 4, pp. 233-264, 1942.

Gray, Netta E., Notes on algae from two warm springs in Arkansas: Am. Mid. Nat., vol. 25, no. 2, pp. 469-471, 1941.

Höfler, K. und Legler, Fr., Uber die Salzresistenz einiger Diatomeen aus dem Franzenbader Mineralmoor: Beih. Bot. Centralbl. Abt. A., 60, heft 1/2, pp. 327-342, 1 fig., 1940. Contains results of some experiments in which several species of fresh-water diatoms were subjected to increasing concentrations of sodium chloride solution up to 1.8 M.

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ECOLOGIC RELATIONSHIPS OF SOME RECENT AND FOSSIL FORAMINIFERA

by

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Assemblages of foraminifera in fossil marine sediments are one of the most prevalent and dependable guides to the biotic conditions and conditions of sedimentation which existed in ancient seas. The species that make up these assemblages vary within a geologic horizon, and in adjacent strata, because differences in temperature, depth, salinity, oxygen tension, pH, food, substratum, and turbulence have a profound effect upon the success of most species, although some tolerate wide variations in these conditions and are therefore widely distributed. The reworking of the sediments from previous horizons and the transportation of the tests by currents often extend the apparent distribution of species, and one of the objectives in this work is to attempt to establish criteria that will contribute to a better understanding of this problem.

Foraminifera living in the intertidal zone are subjected to a wide range and abrupt changes in ecological conditions compared with those living in the sublittoral zone, therefore populations in these two life zones usually have few species in common, although the tests from both zones become mixed in offshore sediments. If we presume that the response to environmental conditions in species showing similar types of test morphology have remained relatively unchanged for long periods, then any attempt to determine the probable boundary of a geological coast line from assemblages of foraminifera rests upon our knowledge of these mixed assemblages.

Foraminifera of the Littoral Zone: The success of foraminifera living in the intertidal zone depends largely upon their ability to make rapid readjustments to a changing environment, the protection afforded by the macroflora living in pools and lagoons, and the ability of the foraminifera to retain their position in this habitat against the scouring action of the surf. The selective elimination of certain groups by surf action and other adverse conditions including the intermittent replacement of food organisms by the changing tides are responsible in part for the types of tests produced by species inhabiting this zone. Species having small depressed tests that adhere closely to the substratum are not easily dislodged by currents and are free to graze upon the microflora that develops on most surfaces. These are abundantly represented by species of Spirillina, Patellina, Discorbis, and Cymbalopora. Larger species including those of Sorites and Amphisorus having thin discoidal tests retain their position on the flattened surfaces of algae or grass by constructing a partially enveloping nest-like structure composed of diatom frustules and other debris gathered from the water and held together by animal cement. These feed upon the phytoplankton and to a lesser extent upon the organisms that develop within the reach of the extended pseudopodia which amounts to little more than the diameter of the test. Species of Planorbulina, Acervulina, and Cibicides become permanently attached to the substratum, the ventral surface of the test conforming to the surface of the algae or other object upon which it rests. Following attachment these species are almost entirely dependent upon water borne food. Peneroplis pertusus succeeds in this habitat because the depressed test offers little resistance to the water as it swings to and fro like a weather vane although one side of the test is usually in contact with the substratum. In the deeper more protected portion of the habitat afforded by the densely growing fronds of algae, species of Calcarina are often numerous. These are provided with long spines perforated by numerous pseudopodial pores that are the distal openings of a complex system of canals. The pseudopodia extending from these spines are usually in contact with several surfaces and the foraminifera are not easily dislodged by the water driven through the algae by the breaking surf. Still deeper within the protection of this habitat, species of Elphidium and Amphistegina with thick lens-shaped tests are often numerous. These species which remain unattached are free to graze upon organisms both in the plankton and in the substratum upon which they live. Patches of Halimeda and areas covered by dead corals are usually a poor source of foraminifera unless they support a dense moss-like growth of smaller algea, when the hardier species of Discorbis and Calcarina are usually numerous. Where dead corals are scoured by surf action Homotrema and related genera having erect stalks and numerous branches thrive. These, like the corals they so closely resemble, depend entirely upon water borne food for sustenance. Few living foraminifera are to be found within the zone of reef building corals.

Foraminifera of the Sublittoral Zone: Below low tide level and extending to depths that vary with the latitude and the clearness of the water but seldom exceeding 20 meters there is a zone that is comparable in many respects to that discussed. This zone supports a foraminiferal fauna that includes species that have their counterpart in the intertidal zone, but because conditions here

are more stable and food more abundant the tests are larger, the walls thicker, and the need for a rigid means of attachment reduced except where the beds are exposed to strong currents. In this life zone species of Calcarina provided with long spines are often replaced by the larger more heavily spined species of Baculogypsina and Tinoporus. Larger fossil species with similar canaliculated spines and columns probably lived upon growths of algae at comparable depths. Species of Amphistegina that inhabit this zone are often twice the size of those found in the littoral zone as are also those of Elphidium, and since there is usually less need for protection from currents at this depth the latter is often found on sand or even mud bottoms. Peneroplis pertusus is also replaced by the larger species of the genus Amphisorus and Sorites by the larger genus Marginopora. Gypsina with its large nearly spherical test and unstable base is also found in this habitat.

In a shallow sea where the light penetration is sufficient for photosynthesis to depths of from 20 to 40 meters, the bottom may be partially covered with patches of algae, and where this condition occurs populations of foraminifera may include species found in the littoral zone suggesting that depth alone is not an important factor in distribution. At these depths we also find other genera including the elongated spindle shaped tests of Alveolinella and the large planospiral tests of Heterostegina. Where the bottom is covered with sandy mud, the range of Heterostegina extends into these areas and here we also find the somewhat heavier tests of Operculinella. On a flocculent mud bottom these two genera are replaced by equally large Operculina in which the thickness of the test is much reduced in the umbilical area, facilitating movement over the soft mud. Where the mud is not excessively soft large species of Elphidium with bilaterally symmetrical tests that rest on one side, and equally large species of Rotalia having bi-convex but not bilaterally symmetrical tests that rest upon what is usually referred to as the dorsal surface are numerous. Where the mud is little more than a colloidal suspension, minute species of foraminifera or species such as Rotalia pulchella that are provided with exceedingly long slender spines that support the tests at the surface of the muds are often abundant.

Populations of foraminifera usually consist of many species but in certain samples more than 95 per cent of all individuals belonged to a single species. Those most frequently observed by us include Rotalia pulchella, Operculina complanata, and Tinoporus baculatus. At Sanoer on the island of Bali in the Netherlands East Indies the latter occurs in such numbers that it was used to gravel the walks in the vicinity of the aquarium and elsewhere. Comparable numbers of Operculina were found on the Sumatra side of Strait Sunda in 20 meters of water. In shallow lagoons where the temperature of the water on sunny days exceeded 40° C. or 104° F., washings from algae often contained comparable numbers of the smaller Rotalia calcar.

History of Tests Found in Sediments: Foraminifera usually terminate their existence in one of three ways. They either reproduce, are ingested as food by larger organisms, or become buried in the sediments during periods of wind

induced turbulence to depth from which they are unable to escape. The cause of death determines to some degree the condition of the tests found in the sediments. It was determined from material produced in cultures that when a foraminifer reproduces asexually all of the protoplasm and a portion of the calcium carbonate contained in the parent test is utilized in producing the new generation. This is also the case in the production of gametes prior to sexual reproduction. In species of Patellina, Discorbis, and Cymbalopora the resolution of the parent test extends to the removal of the septa and the ventral walls of the larger chambers so that all that remains is the fragile disintegrating dorsal portion of the test. This, however, is not the case in most genera since it was observed that following reproduction the walls of the tests of Cornuspira, Miliolina, Bulimina, and similar forms are merely reduced in thickness and only occasionally is the end of the test bearing the aperture destroyed. In larger species the septa between the chambers may be partially removed and the canals and foramina much enlarged. This is exemplified in megalospheric tests of large species of Elphidium in which this partial resolution of the test also results in passages between the proloculum and all adjacent chambers where formerly only one chamber communicated with the proloculum. Therefore it is possible to distinguish from ground sections tests individuals that had reproduced from those that had died from other causes.

A further resolution of the tests of foraminifera that had reproduced results when sediments including these tests are ingested by annelids, holothurians, and other organisms that feed upon the organic matter contained in the sediments. Living foraminifera are also ingested by these and other invertebrates particularly echinoderms and crustaceans some of which, when other food is sparse, use these protozoa as their principal source of food. The digestive tract of certain astropectens often contain many thousands of foraminifera that still retain pigmented protoplasm and the content of the digestive tract of larger holothurians frequently contain tests of species that might be overlooked in samples of sediments taken at random. If we are to judge from the majority of tests recovered from the faeces of the invertebrates referred to, it would seem that these tests could pass through the digestive tract of most invertebrates many times before they would show the amount of resolution that results when a foraminifer reproduces.

Mineralization of the Tests: In our study of the foraminifera of Plymouth Sound, Plymouth, England, it was found that wind induced turbulence during what might be regarded as an average winter so disturbed the bottom sediments that at least 80 per cent of the benthonic foraminifera were buried to depths from which they were unable to escape. Cytological evidence proved that these died some weeks or months later and the protoplasmic content of the tests was removed by bacterial decomposition. In certain regions numbers of tests contain minute spherules of black pyrites of iron, or are completely filled with such material. It is presumed that this mineral is produced in subsurface sediments when anaerobic bacteria utilize sulphates as a source of oxygen and release hydrogen sulphide which in turn produces the pyrites from soluble iron salts. The occurrence of the pyritized tests may be related to the bacterial decomposition of the protoplasm of the foraminifera that had died as a result of being buried during periods of turbulence or when the bottom was disturbed by strong currents. In the Java Sea pyritized tests are numerous along the north coast of Java where the water is shallow and the terrigenous material in the sediments is largely volcanic in origin and are rare near the

south coast of Borneo where the sediments are non-volcanic.

The tests of most foraminifera taken on mud bottoms in this region are completely filled with finely crystalline aluminum silicate as was determined from X-ray spectrographs of decalcified foraminifera. It is interesting that although glauconite is abundant in this region and the mother material of this substance is presumed to be clay or colloidal silica mixed with a little organic matter, glauconitic casts of foraminifera are exceedingly rare. In regions where glauconitic casts of foraminifera are numerous the chitinous membrane that lines the chambers and separate the laminations in the walls of the test may contribute to the production of the organic acids necessary in glauconization.

On a sandy beach exposed to heavy surf the tests of foraminifera are soon eroded or sorted and redeposited where there is less agitation in the water. When a test is worn by erosion or dissolved by chemical agencies in the sediments or in the digestive tract of organisms that feed upon these protozoa, the mass of calcium carbonate that fills the umbilical region and the radiating septa between the chambers where they join the sutures are the last to disintegrate. Where these eroded tests are most numerous, badly worn fossilized tests probably derived from a previous horizon and infiltrated with various minerals are usually abundant. The size and structure of the tests of most foraminifera is such that they are not easily broken, however broken tests are numerous in certain regions and from broken tests still containing protoplasm found in the stomach content of shrimps and other crustaceans provided with crushing jaws it seems that the feeding activities of these invertebrates are largely responsible for the broken tests found in sediments.

Appearance of Living Foraminifera: The color of foraminifera is of little significance to the micropaleontologist, although it is interesting to be able to visualize the probable appearance of the living organisms whose skeletal elements are of major importance in one's work. The color of most species of foraminifera is fairly uniform throughout the geographic range although it does vary with the decreasing transparency of the test as it increases in size and thickness, the number of zooxanthellae contained in the protoplasm in those species in which these symbiotic algae occur and is also influenced by the nature of the food available as is easily demonstrated when pigmented species are maintained in a balanced aquarium. Foraminifera preserved in formalin and stored in a dark place often retain their color for many months. Less than half grown Alveolinella are a vivid sky blue becoming paler with a tinge of yellow as they approach maturity. Operculina is a pale gray green, while Heterostegina is somewhat greener, and Operculinella is light green. Tinoporus is a rich brownish green, while the glass like transparency of the tests of Amphistegina shows the protoplasm to be a vivid green that is at times flecked with red. Elphidium crispum living in tide pools is bright green, while the larger E. craticulata living in the sublittoral zone is a lustrous creamy white. Species of Discorbis range from the bright red of D. patelliformis to the dark brown of D. globularis, the latter color being due in part to the

dark brown chitinous membrane that lines the earlier formed chambers. Peneroplis pertusus is lavender with a bluish cast, and Archaias light blue verging into dark grey green. Most species of Calcarina are a vivid green but this is overcast by the whiteness of the numerous calcareous spines that cover the test, Rotalia calcar with its smaller spines shows this color more clearly. Pyrgo, Triloculina, Quinqueloculina, and other Miliolids are chalky white although when viewed with transmitted light they appear light green or brown where the chitinous lining of the chambers is thickened. Sorites and Amphisorus are also whitish with light green showing through the thin walls of the numerous minute chambers.

In this report we have only discussed those genera and species of foraminifera that are most numerous or conspicuous in the littoral and sublittoral zones of tropical and subtropical regions. More exact data concerning these and other problems including data on the population per unit area on the floor of the sea and the probable rate at which foraminifera contribute tests to the sediments in specific areas will be presented in papers now in preparation.

ECOLOGY OF SOME PERMIAN BRACHIOPODS

by

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U. S. National Museum

For two years the writer has carried out a program of preparing fossils by dissolving them from limestone with dilute acid. This program has yielded some fine material showing ecological features as well as biological characters. To date about 1 1/2 tons of Permian limestone from the Glass Mountains north of Marathon, Texas, have been dissolved in acid. The resulting freed fossils include numerous productid brachiopods that furnish some information as to how these peculiar animals lived. These specimens show that some genera of productids were attached when young but either broke off the attachment or outgrew it in later life. Others were attached throughout life. The material also shows that certain brachiopods now referred to the genus Aulosteges were well provided with spines and were attached while young or throughout life. Aulosteges magnicostatus Girty for example was cemented by the beak and further buttressed by stout marginal spines that are cemented to the attachment base.

The species Productus leonardensis King, common in the Upper Leonard limestone, was attached by hinge spines when young but in the adult condition it lived free on the bottom surface supported by the peculiar wide marginal frill and steadied by long spines that extended obliquely from the cardinal extremities.

3/ Published by permission of the Secretary of the Smithsonian Institution.

A small productid related to P.? pileolus Shumard was attached throughout life. Several specimens show this small species attached by the beak in a vertical position and anchored by long spines cemented to the shell surface on which it is attached.

Some excellent specimens of Avonia give a clue as to the possible habits of this genus. The shell was provided with two kinds of spines: long straight spines that extended obliquely from the cardinal extremities and long body spines which curved over the shell margins. Because the ventral valve was the heavier the shell must have settled with the ventral valve down and rested on the curved surfaces of the body spines and was steadied by the long oblique spines on the cardinal extremities. If the shell were turned over by a current, it would rest on the ends of the curved body spines. Thus the spines kept the shell above a firm bottom and permitted the dorsal valve to open regardless of the position of the animal.

Other fine ecological material obtained consists of clusters of the genus Richthofenia showing the long attachment spines in position. Other specimens of Leptodus preserving several individuals attached show clearly the ostreiform habit of the genus.

While collecting in the Glass Mountains the writer was fortunate in discovering some unusually large specimens of the rare genus Scacchinella which approach six inches in length. These specimens lived in large clusters each individual cemented to some part of the ventral valve of its neighbor to form a reef-like mass.

ENVIRONMENT OF EARLY PALEOZOIC NAUTILOIDS

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Faunas in which nautiloids dominate either because of great abundance, size, or both, occur sparingly in the geological column from the Beekmantown dolomites well on into the Carboniferous and Permian. Sixteen such associations have been studied closely in the field, and the conclusions reached have been correlated insofar as is possible with additional data from the study of collections and literature. In the early Paleozoic, cephalopods occur commonly with abundant gastropods and trilobites, but brachiopods, bryozoa, and pelecypods are either altogether absent or very rare. Beyond the Devonian the decline of trilobites causes the assemblage to lose its identity, and fragmentary fish remains are not uncommon. Frequently the association occurs in conjunction with a bioherm, usually algal in the Ordovician, but predominately coral in the Silurian. The "nautiloid facies" usually occurs in massive hard limestones, though a few significant associations

occur in coarse grained arenaceous sediments. Beds carrying such a fauna are generally extremely limited both geographically and stratigraphically, in some cases being little more than lenses.

Frequent recurrence of this nautiloid facies suggests that a natural association is involved instead of the chance superposition of current transported nautiloids into an environment originally inhabited by gastropods and trilobites. While it is evident that the cephalopods are better equipped for transportation after death by virtue of gas within nearly closed camerae, there is no good direct evidence for assuming that any such events were responsible for the presence of cephalopods in strata where they make up a conspicuous and often dominant portion of the fauna. Orientation of cephalopod shells by currents has been invoked to support this hypothesis. In two cases which have been studied closely, in the Valcour limestone of the Chazyan of the Champlain Valley, and in the Laurel limestone of the Clinton of Indiana, it can be demonstrated that parallel arrangement of the shells is the result of currents acting upon conchs which had been previously buried, partially filled with mud, and the closed camerae of which had been filled with inorganic calcite. Reworking by waves and currents has caused such shells to break, the break occurring through inorganically deposited calcite within the camerae. In such cases parallel arrangement of the conchs is indicative of the presence of relatively strong currents at the time when reworking occurred, but has no bearing whatsoever upon the possibility of transportation of gas-filled conchs prior to burial. It is suspected that similar conditions may obtain in other strata in which cephalopods, particularly orthoceracones, are oriented in a parallel direction, notably the Middle Trenton of New York, the Black River of New York and Ontario, the Fort Cassin beds of the Champlain Valley, and the cephalopods of the Lecanospira zone of the Beekmantown near Ft. Anne, New York.

A cephalopod faunule from a single lens in the Cynthiana limestone, Trenton, of Kentucky (Flower, 1942,) where exotic species occur in a vertical position, shows that such shells had probably contained gas in their camerae, and may have floated. The shells sank to the bottom when there was still enough gas retained within the chambers so that the phragmocone was elevated while the living chamber rested on the bottom, and in this position the shells were buried in a lime sand. All of the species in this association are new, and have affinities with species from such remote regions as the Big Horns, Anticosti, Percé, and Manitoba. Nevertheless the condition of the shells is such as to suggest that they were not transported any great distance by currents. No trace of surface abrasion or solution can be found on these shells, such as would be expected had they been floated about for any considerable period of time.

Quite probably extensive transportations of nautiloid shells is not applicable to any fauna rich in numbers of species and individuals. Rather it is to be expected that such chance straying of dead shells is represented by specimens which are few in number and which may be exceedingly fragmentary. It is remarkable that brevicones appear to be confined to specific facies, as in the Devonian of New York, where different species characterize the contemporaneous Naples and Ithaca facies of the lower Upper Devonian. (Flower, 1939,

pp. 14-15.) It is believed that such shells as may occasionally be transported from their normal environment may frequently be so affected by solution and breakage as to be preserved only as undeterminable fragments if at all. While it is exceedingly difficult to demonstrate that nautiloids have been carried by currents after death, an occurrence was found for which this explanation seems to be reasonable (Goldring and Flower, 1942). The typical Schoharie grit is particularly characterized by nautiloids, and its fauna contains many species known from no other formation. In tracing the Schoharie grit it was found that a marked faunal and lithological change occurs, and that beds contemporaneous with the Schoharie represent deposition in deeper and cooler water. In most localities cephalopods are conspicuously absent from this facies. However, a few of the characteristic Schoharie types have been found some twenty miles from the disappearance of the typical Schoharie lithology. These shells are few and fragmentary, and it seems that their presence outside of their normal environment may be best explained by transportation of dead gas-filled conchs by currents.

There are many genera and species of nautiloids in the Paleozoic, and it is not to be expected that all inhabited the same environment. In the Devonian of New York certain cephalopod genera appear to be confined to a limestone facies, appearing in the Onondaga limestone, again in the Cherry Valley limestone near the base of the Hamilton, and again in the Tully limestone at the top of the Hamilton. In contrast, a fauna of small Pseudorthoceratidae and the Rhadinoceratidae seems to be particularly characteristic of the shales of the Hamilton, apparently thriving well in a sea which was receiving considerable clastic material. The arenaceous Upper Devonian beds of the Penn-York embayment seem to have been an ideal environment for the development of the Bradfordoceratinae, which are not only abundant, but sometimes attained immense size there. However, few other types appear in this association and all are relatively rare.

In the Cincinnatian, cephalopods occur commonly in thin bedded layers in association with pelecypods, gastropods, and trilobites. Such associations are found in the Southgate, again in the Corryville and again in the basal Arnheim, and in parts of the Waynesville. The incursion of exotic cephalopod types in the Richmond is most marked in the Saluda formation, where massive beds of fine-grained light-colored limestone form a very close approach to the lithological conditions of the Red River series of Manitoba and the Shanmattawa limestone of Hudson Bay. It is probably significant that the incursion of the arctic fauna can be correlated in part with the appearance of conditions of sedimentation in the Cincinnati area not unlike those of the arctic embayment where this fauna is better developed. Indeed, it is suspected that the appearance of many of these cephalopod types in the Cincinnati area had to await suitable ecological conditions and that the "Richmond" fauna of the arctic embayment may be in part Covington or even Trenton in age. Certainly the problem must be reexamined in the light of the facieological role of many genera and species which have come to be considered "diagnostically" Richmond in age.

A vast amount of data leads to the belief that nautiloids were very largely facies organisms, benthonic to a very great extent, and that they were much more restricted by environmental conditions than their potentially nektonic gas-filled shells would lead a casual observer to believe.

Additional evidence of the mode of life of orthoceracones indicating that they made up a normal part of the faunal association, and that they frequently rested and crawled upon the bottom, is found in the presence of feeding trails in several formations of the Cincinnatian, occasionally with shells at the end of the trails. In association with such markings are found Treptoceras (Flower, 1942) and "Endoceras". In the Ithaca shales similar markings are associated with Petryoceras in the Sherburne member, and with various smooth shelled Pseudorthoceratidae and with Bactrites in higher beds. Cephalopods were, at least in part, responsible for the trails which have been included under the name Fucoides graphica. Such trails of the Ithaca region have been figured by Clarke (1917, pl. 20-21.)

The study of the role of nautiloids in fossil environments requires a close examination of each association independent of others with special reference to history of deposition of the strata. Such investigation has yielded evidence of interest in other ways. Indications of extensive reworking of strata have been found. In some cases, as those noted above, reworking has removed the shells from their original matrix, broken them, and currents have caused them to lie parallel to each other. In other cases, as in the Cynthiana lens noted above, sinking of wave base has affected only the upper part of the bed, for there the upper part of the lens has been removed subsequent to the deposition of inorganic calcite in the cephalopod shells. Similar submarine erosion may account for the examples of destruction of the upper part of the cephalopods of the Cape Calhoun beds noted by Troedsson (1926). Perhaps such reworking, sometimes regarded as interformational, is much more widespread than is generally believed. This is important as it shows that certain phenomena formerly thought to indicate transportation of shells by currents have no bearing on the problem.

It is as yet not possible to evaluate in very satisfactory terms the ecological conditions which favored the development of the cephalopod facies. Evidence of reworking suggests relatively shallow waters, as do the facies and paleogeographical conditions of the Schoharie grit. It is possible also to conclude that most nautiloids preferred seas which did not receive a rapid accumulation of clastic material. Beyond that it does not seem possible to generalize with safety, partly because of undetermined factors involved, but chiefly because the nautiloids are too large and varied a group to lend themselves to broad ecological generalizations.

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ECOLOGICAL STUDIES OF LATE PALEOZOIC FAUNAS

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Many strikingly unusual faunal assemblages in the late Paleozoic have been long known and long attributed to unusual ecological conditions. These include great and rather local accumulations of crinoids, of cephalopods, of reef-forming animals and plants, and of inhabitants of areas characterized by black shale deposition or by oolitic limestone deposition. The conditions for such assemblages are constantly being studied by paleontologists specializing on faunas of late Paleozoic time. Unusual fossil assemblages other than those mentioned are being discovered each year. Likewise, many late Paleozoic genera and species have long been known to be more indicative of certain sets of ecological conditions, especially within a given age range, than of closely restricted ages. Of these also, new discoveries are being made and new relationships are being found each year. No stratigraphic correlation based on fossils is made without some thought being given to possible ecological influences, and scarcely any stratigraphic study is completed without yielding some ecological data of interest. Because so many of the ecological observations are isolated ones, it would not be feasible in a short resumé to try to mention very many of them individually. Of several larger studies involving ecological investigations, two examples may be of interest. One is of a completed study; the other, of a study in progress.

(1) The Louisiana limestone of early Carboniferous (Mississippian) age consists in typical areas in Missouri of a lower few inches of dolomitic clay overlain by an alternating series of 3 to 10-inch dense lithographic limestone beds and thin dolomitic clay partings. Certain elements of the fauna, notably the pelecypods and the Conularias, are largely restricted to the lower few inches of dolomitic clay. A great proportion of the fauna consists of small individuals, either dwarfed or young. Fossils are much more abundant in the dolomitic clay partings than in the limestone beds that alternate with the partings. From the nature and distribution of the elements in the faunas, the kind and variations of the rocks, the distribution and variations in thickness of the formation, the structural relations in the area

of study and from the interrelations of these and other factors, it is concluded that the Louisiana limestone fauna lived in an enclosed or partly enclosed basin in warm, shallow, little-agitated waters. It is also concluded that the environmental factors in this basin frequently and regularly changed to halt the deposition of dense limestone and to initiate the deposition of dolomite or of dolomitic clay, that the waters were frequently more concentrated than normal sea water, and that the high concentration limited the sizes to which many species could grow.

(2) The late Paleozoic faunas of Alaska occur in widely separated areas and comprise many zones of different ages and of different lithologic and faunal facies. Field work done in 1940 had as one of its purposes the gathering of data on the distribution of the various elements in the faunas with respect to lithologic facies as well as with respect to stratigraphic occurrence. Approximate numerical data of several kinds were also gathered. Additional collections were obtained from significant areas. In many regions it was found that the fossils occurred in beds that had been connected in one way or another with much igneous activity. Investigations are in progress to determine what affect, if any, this activity had on the compositions of the faunas. Investigations already made suggest that the Permian faunas were largely arctic rather than either eastern or western faunas. Further study is expected to yield data on many ecological problems. One problem is to determine whether it is significant that some Alaskan Permian forms occur in the United States in the typical Phosporia formation which contains little igneous material, whereas other Alaskan Permian forms are known to occur only in rocks farther west which have great quantities of materials of igneous origin in them. The ecological problems of the Late Paleozoic faunas of Alaska are being studied in conjunction with a study of their stratigraphic and phylogenetic relationships.

MARINE ECOLOGICAL WORK ALONG THE GULF COAST OF THE UNITED STATES

By

Gordon Gunter

From the biological standpoint the Gulf Coast is the least known marine area of the continental United States. A great deal remains to be learned about the species of organisms present and adequate distributional data for most species have not been acquired. This situation presents a greater than usual handicap to anyone carrying on ecological work in the Gulf of Mexico. This statement is more true of the western Gulf than the eastern part, for collecting has been more intense in Florida.

In 1938 the Fisheries Biological Laboratory of the Fish and Wildlife Service was established near Pensacola, Florida, and it remains today the

most fully equipped marine station on the Gulf of Mexico. Adequate facilities and quarters are maintained for non-resident investigators. The Louisiana Department of Conservation has a small station and laboratory at Grande Pass devoted exclusively to oyster problems carried on by the state. Louisiana State University maintains a summer marine station on Grande Isle, Louisiana, devoted chiefly to the instruction of students and surveys of the flora and fauna of that region. 4/ Independent investigators are welcomed at all seasons. The Marine Laboratory of the Texas Game, Fish and Oyster Commission at Rockport, Texas, is not equipped for experimental work and amounts to a field station. The University of Texas is starting courses in marine biology and oceanography and plans to obtain facilities for this work along the Texas Coast. The University of Miami is not on the Gulf of Mexico, but may be included in the general region. A field station on Elliott Key is operated for the instruction of students. Plans for a marine station have been postponed because of the war.

Work done in the past. -- Ocean going vessels of several institutions in this country have made collections in the Gulf of Mexico and deposited specimens in various museums. Although the information gathered on distribution of flora and fauna, chiefly the latter, is of great value to ecologists, the surveys conducted were not specifically of an ecological nature. The first attempts on the Gulf Coast to examine the relations of organisms to each other and the physical aspects of their environment were surveys of oyster beds in west Florida. The beginnings were crude from a biological standpoint for the earlier surveys were made by young Navy Ensigns at the request of the U. S. Fish Commission. However, the clarity and conciseness of their descriptions of general features of the beds and bottoms could well be emulated today. Later surveys were conducted by Moore, Danglade, and others of the U. S. Bureau of Fisheries, the latest being the survey in Texas by Galtsoff in 1926. These reports gained in scope as more knowledge was obtained. The most extensive work to date on the life history and factors influencing the distribution of oysters and oyster beds on the Gulf Coast was carried on by Hopkins in Texas in 1930. Burkenroad and later Pearse and Wharton worked on oyster enemies. The paper by the latter workers is valuable in its ecological aspects and for the lists of animals found in Apalachicola Bay.

The oyster surveys conducted on the Gulf Coast have been carried on as studies of commercial fisheries but have been almost purely ecological in nature. Oyster "reefs" are definite associations of organisms, mostly possessing hard parts. They might be compared to underwater islands in the bays and many organisms associated with them are found nowhere else. The oysters themselves change shape and ways of growth in response to different environments in a definite way, more so than the large majority of shelled animals. There are large deposits of oyster shell under the bottoms of bays on the Gulf and Atlantic Coasts of the United States, that probably were living "reefs" 25,000 to 150,000 or more years ago. Other shell beds of this type

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4/ In a letter written December 4, 1941 Director E. F. Rehre reported that a molluscan check list and a report on the Callianassidae were ready for publication.

are now on land. A knowledge of the ecological information concerning oysters, especially salinity environmental limits, is of importance to students of the recent geological history of the shorelines of the Gulf of Mexico, and for this purpose it is probably not too much to say that no other recent animal of the shallow coastal waters is so important in interpreting past conditions. It must be added, however, that an extensive ecological study of oyster "reefs" in all aspects has not been made. A study of the distribution of oyster "reefs" correlated with hydrographic features of the bays has never been made. When this work is done the results should be of interest to geologists. It is interesting to note that some of the foundational concepts of ecology arose from the studies of Möbius on oyster "reefs" in the North Sea.

A sample bibliography of ecological work on oysters on the Gulf Coast is given here.

Swift, Franklin, Survey of the oyster regions of St. Vincent Sound, Apalachicola Bay, and St. George Sound, Florida. Appendix 4 Rept. U. S. Comm. of Fisheries for 1896, pp. 187-221, 1897.

Moore, H. F. and Danglade, Ernest, Condition and extent of the natural oyster beds and barren bottoms of Lavaca Bay, Texas. Appendix II, Rept. U. S. Comm. of Fisheries, 1914; 45 pp., 1915.

Galtsoff, Paul S., Survey of oyster bottoms in Texas. Invest. Rept. No. 6, Bur. Fisheries, 1; 1-30, 1931.

Hopkins, A. E., Factors Influencing the spawning and setting of oysters in Galveston Bay, Tex. Bull. Bur. of Fisheries, 47: 57-83, 1931.

Burkenroad, Martin D., Notes on the Louisiana conch, Thais haemostoma Linn., in its relation to the oyster, Ostrea virginica. Ecology 12: 656-664, 1931.

Pearse, A. S. and Wharton, G. W., The oyster "leech", Stylochus inimicus Palombi, associated with oysters on the coasts of Florida. Ecological Monographs 8: 605-655, 1938.

By far the greatest amount of ecological work and other biological work done on the Gulf of Mexico was carried on between 1908 and 1939 at the Tortugas Laboratory of the Carnegie Institution of Washington at Dry Tortugas, Florida. During the time of its existence it was the leading marine station in the Gulf region. Papers were published in a volume first known as Papers of the Tortugas Laboratory of the Carnegie Institution of Washington. Later the series was changed to Papers from the Department of Marine Biology. Subsequently, the name was changed back to the first title. There is no need to list the papers from this well known series. They are available to most workers and any geologist beginning work in the Gulf of Mexico can probably find something related to his problems in these publications. There are articles on diatoms, foraminifera, papers on corals and coral reefs by Vaughan and later by Yonge, as well as papers on echinoderms, various marine worms, and, in short, practically every animal group of this region. Complete

ecological surveys encompassing all animal and plant groups were not made but there are dozens of papers relating partly to the ecology of one or several species of organisms. In later years emphasis was put on experimental biology. Unfortunately for the students of marine biology and oceanography, changes in the interests of the Carnegie Institution lead to abolishment of the Tortugas Laboratory in 1939, although papers have continued to come out.

In 1931 the U. S. Bureau of Fisheries started a study of the commercial shrimp on the South Atlantic and Gulf Coasts extending from North Carolina to the Mexican border. This project was handled by the Shrimp Investigations Staff with headquarters in New Orleans. It was carried on along the general lines used in attacking other fisheries biological problems. Since a great deal of the work has been concerned with movements, migrations and life history of the shrimp, a large part of it has been an ecological study. Surveys have been carried on from shallow estuarine waters out to the offshore limits of the shrimp distribution and beyond in Texas, Louisiana, Florida, and Georgia. Although there is still much to be learned about the ecology and life history of commercial shrimp, it is probably better known than any other marine animal in the Gulf of Mexico. A great deal of data has been collected and much remains to be published in the future. The chief publication to date is Weymouth, F. W., Lindner, Milton J., and Anderson, W. W., Preliminary report on the life history of the common shrimp, Penaeus setiferus (linn.), Bull. Bur. Fish. 48: 1-26, 1933. Collections of several animals other than shrimp have been made and work on them in the future will be of interest to students of marine biology.

In 1937 Riley working from the "Atlantis" of the Woods Hole Oceanographic Institution did some work on the hydrography of the area adjacent to the Mississippi River mouth. (Riley, Gordon A., The significance of the Mississippi River drainage for biological conditions in the northern Gulf of Mexico, Sears Foundation: Jour. Marine Research 1:60-74, 1937). He concluded that a large amount of phosphorus was brought down the Mississippi River and exists in higher concentration around the river's mouth than in other parts of the Gulf. Correlated with it is a greater than usual abundance of phytoplankton.

Ecological work on fishes of the Gulf of Mexico has not been extensive. The most complete published work, which was partly devoted to observations of the ecology of Gulf fishes, is that of Pearson. (Pearson, John C., Natural history and conservation of the redfish and other commercial sciaenids on the Texas Coast. Bull. Bur. Fisheries 44: 129-214, 1929). It was carried on as a fisheries biological study. Pearson gathered much new information about the more important shallow water fishes of the northern Gulf of Mexico. The writer, while working with the Shrimp Investigations Staff, did some work on variations of seasonal abundance of Gulf fishes, and, at that time, and later, studied the relative abundance of species to species in shallow Gulf waters.

Gunter, Gordon, The relative numbers of species of marine fish on the Louisiana Coast. Amer. Nat. 72: 77-83, 1938 a.

Gunter, Gordon, Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. Ecological Monographs 8: 313-346, 1938 b.

Gunter, Gordon, Relative numbers of shallow water fishes on the northern Gulf of Mexico, with some records of rare fishes from the Texas Coast. Amer. Midland Nat. 26: 194-200, 1941.

Storey and Gudger compiled observations on marine fishes killed by cold waves at Sanibel Island, Florida. Later the writer made similar observations on the Texas Coast. These observations are of interest to geologists as examples of catastrophic death of large numbers of marine animals. Storey showed that fishes of tropical and subtropical distribution were more readily killed by cold than were fishes of temperate zone distribution. These and other observations are given in the three papers listed here.

Storey, M., and Gudger, E. W., Mortality of fishes due to cold at Sanibel Island, Florida 1886-1936. Ecology 17: 640-648, 1936.

Storey, Margaret, The relation between normal range and mortality of fish due to cold at Sanibel Island, Florida. Ecology 19: 1026, 1937.

Gunter, Gordon, Death of fishes due to cold on the Texas Coast, January, 1940. Ecology 22: 203-208, 1941.

Up to the present these and a few related papers constitute the chief publications relating to the ecology of fishes in the Gulf of Mexico.

In 1937 and 1938 Albert Collier, then with the Texas Game, Fish, and Oyster Commission, carried on a hydrographic study of Copano and Aransas Bays and the adjacent Gulf of Mexico. The results of this two-year study have not been published. When finished, it will be the most complete and extensive hydrographic publication on the bay and estuarine areas of the Gulf of Mexico and will be of particular value to all students of shallow water animals and shallow water geology.

The work of Ladd on the distribution of present day mollusks and comparison with the geological picture of recent coast horizons of Texas was mentioned in last year's report of this committee. The work of Haas on common mollusks of Sanibel Island Florida was also mentioned in the last report.

Of interest to students of marine ecology was the publication in 1941 of "Marine Life in Texas Waters" by Clyde T. Reed. It lists most of the common flora and fauna of the Texas Coast and gives observations of the author made during a period of fifteen years. It was published by the Texas Academy of Science. There are some errors in the bulletin (Gunter, G., Amer. Midland Naturalist, vol. 26, pp. 698-699, 1941), but it is a long step forward.

Robert P. Allen, of the National Audubon Society, has been studying the Roseate Spoonbill in Texas and Florida. He is preparing for publication an article on food and feeding habits, which contains some very interesting ecological observations on the fauna of the shallow salt water flats where the birds feed. His studies of this particular environment are the most extensive made in the Gulf region. Cyprinodontids were the dominant fishes found and estimates of the relative numbers of several species were made.

At the University of Miami, F. G. Walton Smith is making a biological collection which it is hoped will eventually contain all common West Indian marine species. He has carried on preliminary surveys that have shown that as in the Bahamas, the habitat of commercial sponges coincides with areas of great bacterial content. More work will be done.

E. S. Hathaway and William Penfound of Tulane University have recently worked on the ecology of plants of Louisiana salt marshes. Hathaway is continuing with a study of the animal communities of salt marshes near Lake Borgne.

In 1939 James R. Bartholomew, of Harvard University, carried on a survey of marine diatoms from Key West to St. Marks, Florida. The work has since been extended westward, with headquarters at the Fisheries Biological Station in Santa Rosa Sound, near Pensacola.

The work of the Shrimp Investigations Staff, now a part of the Fish and Wildlife Service, continues from their office in New Orleans.

The only work of marine ecological nature now being carried on in Texas is that of the Game, Fish, and Oyster Commission. The food habits of the common porpoise or bottle-nosed dolphin and other points of its natural history have been studied. It has been shown that in the shallow bay waters the food is chiefly mullet, one of the most abundant fishes. Results will be published in the near future.

Offatt's Bayou, a locality near Galveston, with recurrent summer mortality of marine organisms has been studied. The bayou is a blind alley, so to speak, deeper at the inner end than at the mouth. During the summer, boils of fetid, evil smelling water come up to the surface, apparently from the bottom. It was concluded that the small tides of this area do not flush out the bayou, that the inner end acts as a deposition bowl for organic material which putrefies finally, if not at first, under anaerobic conditions, and the products of decay boil to the surface and injure living organisms. Publication will be made in the near future.

A study of the seasonal condition of the Texas oyster has been made and will soon be published. It shows briefly that betterment in condition and fatness of the oyster increases in almost a straight line relationship from the fall months through the winter and into spring just before spawning.

A study of cold-killed fishes and shrimp was carried out during the past winter at the time of a mild cold spell, which yielded information of a different sort than that obtained from the bitter cold wave of January, 1940. The results are in press.

The Laguna Madre along the Texas Coast extending from Corpus Christi to Port Isabel, a distance of approximately 150 miles, and separated from the Gulf of Mexico by Padre Island is one of the most interesting marine environments in the United States. The water is very shallow for the most part and the only outlets are at the two ends. There is very little land drainage into the Laguna and the country is semi-arid. During the summer a great deal of evaporation takes place and during extended droughts the salinity of the water becomes as much as three times that of ordinary sea water, measured in terms of specific gravity. Nearly all fish and marine life is completely exterminated and one worker suggested that salt deposition takes place. The Game, Fish and Oyster Commission cut a pass through Padre Island in 1941 in an effort to bring about greater admixture of Gulf and Laguna waters for the purpose of lowering the salinity. In connection with this, a survey and check of the salinity of the upper Laguna was made every month. It is now carried on every three months. It was found, after heavy rains during the winter and spring of 1941, that the salinity underwent a precipitous drop. Since that time it has risen but it is not above that of saltier bay waters. Concomitant with the salinity drop, there has been a great influx of fish in the region. Observations are being continued.

In general there are two series of bays along the Texas coast. The outer series is separated from the Gulf of Mexico by sandy barrier islands, the inner series is connected with the more seaward bays. Most rivers and drainage empty into the inner bays, which, in most cases, are of lower salinity than other coastal waters. At the present time the writer is making a marine ecological study of fishes and crustacea of Copano Bay, an inner or back bay, Aransas Bay, a front bay, and the adjacent Gulf of Mexico out to five miles offshore at a depth of about sixty-five feet. This covers a salinity gradient from near the mouth of the Aransas River to pure sea water in the open Gulf, over a distance of forty miles. Fishes and crustacea are taken in trammel nets, trawls, small minnow seines and beach seines. About thirty hauls are made at twenty-one stations every month. In addition to temperatures and salinity of surface and bottom waters, the general environmental data are recorded. All species of animals taken are counted and recorded, and up to fifty of every species are measured. The gonadal condition and the food habits of the larger fishes are studied. This work has been carried on for a year and will be repeated for another year. Approximately 60,000 fishes have been handled in this investigation. It will yield information on the seasonal movements, migrations, spawning, and distribution of the animals with respect to their temperature and saline environments. The population of fishes in the two bays and the Gulf of Mexico are generally quite different and movements from one to the other show up clearly as seasonal cycles and changes take place. Aside from the life history of fishes and their movements the most applicable general result will probably be the information on the relation of fishes to the salinity of the environment.

During the past three years the writer has compiled a list of the euryhalin fishes (those that can live in both freshwater and sea water) of the mainland of North and Middle America from the southern boundary of Panama northward. Although not related specifically to marine ecological work on the Gulf of Mexico, it should be of some interest to geologists and students of fossil fishes. There are 130 species of fish on the list. Ten percent of the lower fishes of North America contain approximately thirty-seven per cent of all euryhalin fishes. (The list includes cyclostomes and elasmobranchs). Apparently, lower fishes have a greater tendency to be euryhalin than higher fishes. From northern Mexico and southern Florida northward the lower fishes, below the Acanthopterygii, are in the majority on the euryhalin list. From Mexico southward the reverse status is true. Studies of physiology, palaeontology, and zoogeography in the future will possibly clarify the reasons for this distribution of the fishes of North America. The marine fishes on the list outnumber freshwater fishes by over nine to one, a much greater figure than the two to one predominance of numbers of species of marine fishes over the freshwater fishes. If, as modern theory has it, fishes originated in freshwater, then their descendants seem to be trying to return to the ancestral home. Probably, however, they are activated by the same stimuli which affected their prototypes, the marine ancestors of land animals, long ago. Full publication will be made in the future.

INVESTIGATIONS IN MARINE ECOLOGY CONDUCTED BY THE DIVISION OF FISHERY BIOLOGY, FISH AND WILDLIFE SERVICE

by

Elmer Higgins, Chief, Division of Fishery Biology

Underlying most of the biological investigations of the great marine commercial fisheries conducted by the Fish and Wildlife Service are problems of an ecological nature, concerning the relations of economically important fish and shellfish to the physical and chemical factors of their environment, the complex inter-relationships between groups of marine animals, and the effect of the commercial fisheries themselves on the stocks of fish. In terms of such a broad interpretation, most of the biological studies of the Service might be included in a summary of its investigations in marine ecology. For present purposes, however, there have been included only those current studies which directly employ the methods of ecological research and the results of which are of direct interest and application in this field.

LABORATORY FACILITIES

The bulk of the investigations in marine ecology are conducted at four stations situated on the Atlantic and Gulf Coasts. These are the laboratories at Woods Hole, Massachusetts, Milford, Connecticut, Beaufort, North Carolina, and Pensacola, Florida. The Fish and Wildlife Service station at Seattle,

Washington, while serving as general headquarters for ecological investigations of the Pacific herring and salmon, does not provide comparable research facilities.

Woods Hole, Mass.-- The Woods Hole Station of the Fish and Wildlife Service was built in 1883 by the former United States Fish Commission and for a time served regularly as summer headquarters for the Commission. Its facilities have been used by the biological staff for various investigations related to the marine fisheries of New England, and during recent years have been devoted principally to studies in the field of oyster metabolism. During the summer of 1942 all of the equipment was placed in storage and the buildings were taken over by the Navy for the duration of the war.

The two principal buildings are a three-story residence and a combined laboratory and fish hatchery, both of frame construction. The fish hatchery and a public aquarium occupy the first floor of the laboratory building, while the second floor is devoted to offices and laboratories, the latter equipped with specialized apparatus for investigations of oyster physiology. The small library is housed on the third floor.

Milford, Conn.--The Fishery Laboratory at Milford is a two-story fireproof building of brick and cinder-block construction, occupying an area 70 by 35 feet. The first floor contains the director's office, two laboratories, two small rooms for investigators, and a room for lectures and conferences; and also houses the heating plant, mechanical equipment, and carpenter shop. Chemical, physiological, and biological laboratories are located on the second floor, together with a chemical stock room, balance room, photographic room, and library. All of the laboratories are provided with standard equipment including running sea water. Special facilities for experimental studies include a series of large concrete outdoor tidal tanks, each about eight feet deep, built along the water line. Each tank is individually filled with sea water through tidal gates and the depth of the water can be maintained at three different levels.

Beaufort, N. C. -- The Beaufort Laboratory was built in 1901 on an island situated in Core Sound off the town of Beaufort. During recent years a bridge was built connecting the island with the mainland, so that the town may now be reached by driving about 1½ miles over improved roads. Although the laboratory's equipment for chemical and physiological research is somewhat limited, facilities are adequate for many ecological investigations of the local fauna. A small staff of the Fish and Wildlife Service conducts investigations in the fields of oyster biology and oyster culture throughout the year and approximately a dozen investigators from other institutions are provided with laboratory space during the summer months.

The main building is a two-story, frame structure, the central portion of which is devoted to laboratories, offices and a museum. The wings contain residence quarters for investigators. Other buildings on the island include the director's residence, a hatchery building where the diamond-back terrapin

is propagated, outdoor concrete pens for the terrapins, a garage and a boat house. Fresh water is provided by an artesian well and running salt water supplies the laboratories.

Pensacola, Fla.-- The Pensacola Laboratory is located on a 16-acre island in a protected section of Pensacola Harbour about eight miles by road from the City of Pensacola. The island is connected by a causeway and bridge with the island of Santa Rosa, which in turn has similar connections with the mainland. The main building is a two-story structure containing large and small laboratory rooms equipped with the usual facilities for biological and physiological research. The second floor contains the library and museum and provides storage space. Other buildings adjacent to the laboratory include a shop, covered boat house, dormitory building and mess house, the director's residence, and four other residences. A water tower stores fresh water and two large concrete pools provide facilities for experimental studies of the effect of changing conditions on the physiology of the oyster. Boats attached to the station include a 48-foot cabin cruiser and several smaller craft, for which a deep-water dock and a shallow-water boat basin enclosed by a breakwater have been provided. Extensive flats adjacent to the island have been set aside for future development as experimental oyster farms. Running salt water supplies the laboratories.

SUMMARY OF INVESTIGATIONS

Ecology of the Haddock

Apart from tracing the direct influence of the commercial fishery, investigations of the haddock have considered various physical and biological conditions as possible causes of changes in abundance. Outstanding among these investigations is a study in population biology which demonstrates a direct relationship between the size of the spawning population and the numbers of young that survive the period of infancy. When the number of spawners falls below a determined optimum, few young are produced and hence few reach commercial size. When the number of spawners exceeds the optimum, relatively few young survive-- presumably because the old haddock overrun the nursery areas and reduce food supplies or possibly because the adult fish directly reduce the numbers of young by cannibalism.

Ecology of the Pacific Salmon

1. An oceanographic survey of Bristol Bay and contiguous waters along the Alaskan Peninsula and Bering Sea was begun in 1938 to determine the physico-chemical and biological properties of the marine habitats of salmon and to determine the relation of hydrographic conditions to the oceanic phase of the salmon's life.

This work was carried out through a cooperative arrangement with the Coast Guard which made available its vessel EDWING. At selected stations throughout this area temperature data and plankton samples were collected and

chemical analyses were made to determine the oxygen, chloride, silicate, phosphate, and nitrite content of the water at various depths. The surveys were necessarily suspended during the summer of 1941 and cannot be resumed during the wartime period.

2. Further study of the ecology of salmon in the Bristol Bay area consisted of an analysis of their feeding habits in relation to the availability and abundance of food organisms. This has been accomplished by correlating the stomach contents of salmon taken by experimental fishing operations with data on the numbers and kinds of organisms collected in plankton nets.

3. A recently completed study of the effects of stream flow on the spawning migrations of pink salmon in southeastern Alaska indicates that salmon may begin their ascent of fresh water under a wide variety of conditions, and constitutes a step toward the discovery of the factors governing migration.

Ecology of the Pilchard

In connection with an extended study of the pilchard fishery off the coasts of California, Oregon, and Washington, biologists of the Service are making analyses of hydrographic and meteorological conditions to learn the relation between climatological phenomena and the success of pilchard spawning. As early as 1938 the staff had established a relationship between temperatures prevailing at the time of pilchard spawning and the successful survival of the young. Further investigations have been under way subsequently to determine whether survival is governed directly by temperature or by factors associated with temperature, such as ocean circulation. In cooperation with Scripps Institution of Oceanography a survey of the major pilchard spawning areas was made through three successive seasons. Marterials were collected for a quantitative study of the populations of pilchard eggs and larva and for correlating the size of these populations with changes in hydrographic conditions. These studies promise to indicate the types of hydrographic conditions that favor or hinder survival of larvae.

Ecology of the Pacific Herring

One of the objectives of the staff investigating the biology of the Pacific herring is to determine, by a study of environmental factors, the causes of variations in the survival of eggs and fry from the spawnings of different years. Preliminary investigations were undertaken to measure the effect of temperature and dessication on the survival of herring eggs, which are deposited in the inter-tidal zones along the beaches of Alaska. A satisfactory technique has been developed for hardening, separating, and clearing the eggs in order to estimate the percentage of survival. Indications were obtained that the mortality counts for selected beaches were closely correlated, at least in one year, with the time of exposure. Further investigations in this field will be undertaken as soon as facilities permit.

Ecology of the Oyster

1. A comprehensive program of investigations in the field of oyster biology and its applications to oyster culture was undertaken upon the completion of the Pensacola Laboratory in 1940. Considerable attention has already been given to determining the environmental factors responsible for the periodic occurrence of heavy mortality on public and private oyster grounds, with special attention to the effects of changes in salinity. By controlled experiments in the outdoor concrete tanks at the Pensacola Laboratory it was found that oysters are able to withstand almost pure fresh water for a considerable period of time, but are killed in large numbers by a rapid change from fresh to salt water. It was found also that changes in the salinity of water induce changes in the mineral content of oysters. Conclusions of only a preliminary nature may be drawn at this time, but it is believed that the blood and tissues of oysters lose minerals in water of low salinity, rather than simply increasing in volume by endosmosis.

2. Means of increasing diatom abundance by the use of fertilizing substances have been investigated both in Long Island Sound and in the Gulf of Mexico. Rich cultures of diatoms have been produced in the laboratory by the use of commercial fertilizers. Although the results of these investigations are still inconclusive as to their practical application to the problem of rapid fattening of oysters, indications were obtained in the Gulf Coast studies that oysters remain in better condition in fertilized water than in running sea water.

3. The effect of seasonal changes in the temperature and salinity of Long Island Sound waters on the propagation of oysters has been under investigation for several years. Sampling stations have been established over a 30-mile stretch of the most important Connecticut seed-oyster producing areas and systematic observations have been made on the temperature and salinity of the water and the degree of gonad development exhibited by the oysters. These studies have yielded results of immediate practical application to oyster culture, indicating with considerable accuracy the time when spawning and setting of oysters may be expected.

4. In cooperation with Yale University, studies are under way in Long Island Sound to determine seasonal changes in the concentration of nutrient salts essential to the production of marine plankton. In addition to their scientific interest, these studies should yield results applicable to the problems of oyster culture since plankton organisms constitute the principal food of the oyster.

5. A study undertaken by the Service during the summer of 1942 properly falls within the field of marine ecology in spite of its very diversified nature. The periodic occurrence of unexplained heavy mortality among Louisiana oysters has already been referred to. A thorough investigation is now under way to determine the effect upon the oyster of such adverse environmental conditions as sudden changes in salinity, industrial pollution, drainage of stagnant water from marshes, and the occurrence of large numbers of natural

enemies.

6. Studies of the relation between the oyster and a wide variety of predatory marine animals have been under way in the various coastal laboratories of the Service for several years. As a result of these studies the outstanding enemies of the oyster in each section are known, the extent of their predations has been measured with a fair degree of accuracy, and measures for control of several of the most important oyster enemies have been developed.

ECOLOGICAL PAPERS PRESENTED AT THE DENVER MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

by

F. W. Rolshausen

At the American Association of Petroleum Geologists meeting in Denver in April, 1942, several papers were presented or read by title that should be of interest to anyone studying the ecology of marine organisms. It is hoped that these papers will be published in the near future. The following are abstracts of these papers:

E. C. DAPPLES, Northwestern University, Chicago, Illinois

The Effect of Macro-organisms Upon Sediments

Macro-organisms which may directly affect sediments after their deposition are limited to benthonic forms which burrow for shelter, or in search of food; and those which ingest sediments for the contained organic material. Such changes which are produced in sediments by such organisms are: destruction of bedding, destruction of gradation of grain size, trituration and solution of rock masses and fragments, formation of tubes and burrows, addition of fecal debris, initiation of cementation, bleaching or coloration, and destruction of organic material.

Since the degree of such alteration is necessarily directly proportional to the number of organisms living on the bottom, the greatest changes must occur where the optimum dwelling conditions exist; hence, not in regions of stagnant water, nor where sedimentation is rapid. Organisms which have the greatest effect upon sediments are holothurians and worms, rock borers and echinoderms being secondary. The greatest proportion of holothurians and worms live in the littoral and sub-littoral zones, hence near shore deposits are subjected to the greatest attack by such organisms. Gently sloping bottoms, estuaries, and coral lagoons, where the waters are circulating freely appear to provide the habitats which are preferred by such organisms. In such habitats most of the macro-organisms prefer to live on sediments whose grain size varies from medium sand to silt dimensions, and also where a sandy mud is present.

Hard clay, or soft clay and mud bottoms do not appear to provide desirable conditions for organisms which ingest sediments. Sand which is abundant on the floor of many coral lagoons appears to be a concentrate of coarse and medium sand, the finer material being triturated and carried out by currents, or dissolved in the bodies of organisms.

Fecal pellets so abundantly present in localities inhabited by holothurians, worms, and echinoids appear to be preserved in sediments in the deeper neritic waters, and destroyed in the littoral. In deep waters such material results in phosphatic or glauconitic nodules.

CLAUDE E. ZOBELL, University of California, La Jolla, Calif.

Bacterial Activity and the Transformation of Marine Sedimentary Materials

Significant numbers of bacteria are found in recent marine sediments wherever critical tests have been made for their presence. The total number of bacteria as well as the number of different kinds of bacteria is greatest at the surface of the mud where there are often many millions of bacteria per gram. Both numbers and kinds (species) of bacteria decrease with the depth of the mud cores although several thousand living bacteria per gram of mud representing over a dozen species have been found at the bottom of mud cores exceeding fifteen feet in length.

Bacteria have been isolated from deep sea bottom deposits which attack most kinds of organic matter including highly refractory compounds such as cellulose, chitin, lignin, spongin, agar, and waxes. Most types of protein are attacked with the liberation of ammonia or hydrogen sulfide. Fats and lipins are hydrolyzed by certain marine bacteria with the formation of fatty acids. Vibrio desulfuricans which reduces sulfate to hydrogen sulfide is quite widely distributed in sedimentary materials and the decreasing concentration of sulfate with depth suggests that it is active in situ.

Changes in the organic content, oxidation-reduction potential and hydrogen-ion concentration as well as changes in the amount and state of sulfur compounds indicate that bacteria may play an important role in the diagenesis of sedimentary materials. By decreasing or increasing the hydrogen-ion concentration bacterial activities may tend to precipitate or to dissolve calcium carbonate. Bacteria are present in marine bottom deposits capable of doing either, the direction and magnitude of the change being largely a matter of the organic, sulfate, and nitrate content. By their effect on the oxidation-reduction potential of sedimentary materials bacteria influence the state of oxidation or reduction of such constituents as iron, manganese, and other substances which may be reversibly oxidized or reduced.

Although it is still indeterminate if bacterial activities play a role in the genesis of petroleum, it has been established that they convert organic matter such as marine sapropel into substances which are more petroleum-like by reducing the oxygen, nitrogen and phosphorus content. Moreover, the low Ph (reducing conditions) which bacteria create in certain environments are theoretically conducive to the formation and accumulation of hydrocarbons. Methane-producing bacteria are widely distributed in sedimentary materials but bacteria which produce other hydrocarbons (with the possible exception of complex pigments) have not been demonstrated. On the other hand it is possible that certain bacteria which are known to oxidize hydrocarbons under laboratory conditions may be active on the sea floor where they could prevent the accumulation of hydrocarbons in detectable quantities.

EDWARD MONSOUR, Louisiana State University, Baton Rouge, La.

Fossil Corals of the Genus Turbinolia from the Gulf Coast

The stratigraphic occurrence of the genus Turbinolia in the Gulf Coast Tertiary beds was determined by a study of specimens from 73 localities in Texas, Louisiana, Mississippi, and Alabama. This study shows that the genus ranges in age from basal Midway (Clayton) to upper Vicksburg (Byram). The most common occurrence of the genus is in the Claiborne, less common in the Jackson, and rare in the Midway, Wilcox, and Vicksburg groups. Several new species are described and previous work on the range, distribution, ecology, and evolutionary trends of Turbinolias are discussed.

LOIS T. MARTIN, Stanford University, Palo Alto, California

Eocene Foraminifera from the Type Lodo Formation, Fresno County, California

The Eocene Foraminifera from the type Lodo formation were studied with two main problems in mind: whether it is practical to subdivide the Lodo into paleontologically defined units; and what probable ecologic conditions prevailed during the deposition of the strata. An analysis of the ranges of 144 species permit the postulation of three embryozones. A canvass of the occurrences of genera in modern seas suggests the hypothesis that deposition took place in gradually shallowing, cool temperate waters. Twenty-seven new species and four new varieties are being described.

R. STANLEY BECK, Richfield Oil Corporation, Bakersfield, Calif.

Eocene Foraminifera from Cowlitz River Lewis County, Washington

The Cowlitz River locality is one and one-half miles east of Vader, Lewis County, Washington, in $E\frac{1}{2}$ $SE\frac{1}{4}$ sec. 28, T. 11 N., R. 2 W. At this

locality approximately 200 feet of fossiliferous mudstone are exposed along the west bank of Cowlitz River.

A collection of 65 samples from the above beds at three foot stratigraphic intervals contained 107 species and varieties of Foraminifera. Twenty-five species and eight varieties are considered new. The above species constitute but one faunule. This faunule is the assemblage referred to in introducing the term Saracenaria mackini zonule for the strata on Cowlitz River.

An ecologic analysis of the faunule indicates that the Cowlitz River beds were deposited in a warm tropical sea at the outer margin of the neritic zone and/or the upper bathyal zone.

On the comparison of Foraminifera the Cowlitz River beds are considered upper Eocene and are in part correlative with the Coaledo formation of Oregon, the Tejon, Poway, Kreyenhagen, and Markley formations of California, and to a lesser extent with the Cook Mountain Formation of the Gulf Coast.

FRANK E. IOZO, JR., Texas Christian University, Fort Worth, Tex.

Micropaleontological Analysis of the Fredericksburg-Washita Contact in North-Central Texas

Excavation for the dam across the Red River, five miles north of Denison, Grayson County, Texas, has exposed the entire Kiamichi formation and the lower portion of the overlying Duck Creek formation. Since the section involving the Fredericksburg-Washita contact controversy will in the near future be inundated, samples were collected from the softer shale and marl members and analyzed for micropaleontological evidence.

The Foraminifera, largely benthonic in habit and therefore excellent facies indicators, are sharply restricted between the formations. The Kiamichi assemblage contains elements of the underlying Goodland assemblage and lacks the characteristic elements of the overlying Duck Creek assemblage. This formainiferal break is most pronounced.

The Ostracoda, being more nectonic in habit and thus not as greatly controlled by lithologic bottom-type, appear to be better time indicators than the foraminifera. The Kiamichi ostracodes have close affinities with those of the Goodland. Post-Kiamichi beds in the basal Duck Creek not represented elsewhere along the outcrop in north-central Texas contain a mixed Kiamichi-Duck Creek assemblage. These beds also contain ammonoids (Adkinsites, Elobiceras, and others.) Above these beds the ostracodes are typical Washita species. The beds containing the mixed Kiamichi-Duck Creek ostracode and ammonoid assemblages are faunally transitional. It is suggested that a time division between the Middle and Upper Albian stages be placed at the top of the occurrence of the mixed assemblages.

Supporting, though less conclusive, micropaleontological evidence that the Kiamichi should be included in the Fredericksburg group and that the Duck Creek is the basal formation of the Washita group is recorded in the distribution of fish remains, barnacle plates, holothurian spicules, microcrinoids, and other microfossils.

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